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ANALYSIS OF POLLUTION FROM MARINE ENGINES AND EFFECTS ON THE ENVIRONMENT. SOUTHERN LAKES

H. L. Davis, et al

Boating Industry Associations

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16. ABSTRACT

This study was conducted to determine the effects of two-cycle outboard engine emissions on Florida lakes using leaded fuel and drained and drainless engines. Field investigations were performed in three natural lakes of 2 to 10 acres near Gainesville, Florida. One lake was treated with "drainless" engines and one with engines which "drained" unburned fuel into the water. The third lake served as a control. Biological components and water quality conditions in the three lakes were monitored by routine standard procedures for a time period of 18 months during which motors were operated at the rate of 2.4 gallons of fuel per million gallons of water per day. During the course of the field investigation, there was no overt evidence of any significant effect of motor emissions on the benthic macroinvertebrates, phytoplankton, periphyton, and fish taste; although the data indicated that plant production in the grassbeds may have increased as a result of engine operation. This increase in plant production was evident during the growing season when the availability of carbon dioxide limited plant growth in the grassbed community.

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Lakes		Oil pollution	
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Southern Lakes

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244

REVIEW NOTICE

The National Environmental Research Center, Cincinnati, has reviewed this report and approved it for publication in order that the data may be made widely available and serve as a basis for future studies by others, should they be desired. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency nor does mention of trade names or commercial products constitute endorsement or recommendation for their use.

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water and land. The National Environmental Research Centers provide the multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The northern lakes, southern lakes and laboratory studies were conducted by independent consultants who were subcontractors to the Boating Industry Associations. The project design was approved by the U. S. Environmental Protection Agency and monitored during the course of the study by EPA personnel. As a result of the studies and the contractors' analysis of the data, no significant environmental impacts from outboard motor boating activity were found under the study conditions. However, since it was impossible in this study to cover fully all the diverse factors which may be impacted by emissions from outboard motors, care should be taken in extrapolating the results to situations other than those covered by this specific study. These data are being presented in order that they may be widely available and serve as a basis for possible future studies by others should they be required in considering the implementation of regulations relating to the recreational utilization of the Nation's waters.

A. W. Breidenbach, Ph.D.
Director
National Environmental Research
Center, Cincinnati

ABSTRACT

A study jointly funded by the U.S. Environmental Protection Agency and the Boating Industry Associations, was launched in April, 1971. The study was concluded on March 31, 1973. Major objective of the study was to determine the effects of two-cycle outboard engine emissions on aquatic environments.

This study included field investigations of natural lakes in Florida by Environmental Science and Engineering, Inc., Gainesville, Fla. Field studies were performed in three lakes of 2 to 10 acres near Archer, Fla. No boating activity had occurred on any of the lakes and they received no other pollutional inputs other than the stressing from two-cycle outboard engines. One lake was treated with "drainless" engines and one with engines which "drained" unburned fuel into the water. The third lake served as a control. Leaded fuel only was used. In general, all chemical and biological sampling and data analyses were performed by routine standard procedures.

Engines used in the laboratory and field studies were standard production models. Before use in the field, each engine was "aged" by running the engine for approximately 50 hours, the equivalent of one year of normal operation.

Stress rate for the field studies was established by determining, as closely as possible, the number of motorboats that reasonably could be expected to occupy a given surface area of water under optimum (saturation) use conditions. This optimum stress level was tripled for the purposes of this study, resulting in a stress level of 2.4 gallons of fuel per million gallons of water per day.

The results from the Florida field investigations suggested that outboard motor operation may have increased primary production in the grassbeds along the shore zone where the availability of carbon dioxide limited plant growth. Results from other biological parameters including benthic macroinvertebrates, phytoplankton, periphyton, and fish tainting showed no overt evidence that motor emissions had significant effects. With the exception of carbon compounds, there was no direct evidence of outboard emissions affecting the following chemical parameters; iron, magnesium, chloride, sulfate, fluoride, total solids, suspended solids, dissolved solids, total hardness, conductivity, turbidity, pH, BOD, COD, nitrate, organic nitrogen, ammonia, orthophosphate, and total phosphate.

Motor operation in the southern lakes increased the concentration of dissolved aromatic hydrocarbons, mixed and circulated the lake water, and distributed the hydrocarbon emissions as well as other emissions throughout the lakes. The concentration of aromatic hydrocarbons increased from background levels of less than 0.01 mg/l to levels of 1.0 mg/l during motor operation. When the motors were not operated for two days, hydrocarbon levels declined to less than 0.1 mg/l.

In the Florida lakes, distribution, species composition and diversity of benthic macroinvertebrates were not affected by motor emissions although they were affected by mixing and agitation in a small area immediately beneath the permanently mounted motors where scouring of the bottom sediments resulted.

A detailed research program is recommended to investigate the effects and significance of motor operation on plant production in low alkalinity lakes.

This report was submitted in fulfillment of EPA Grant No. R-801-799 by Environmental Science and Engineering, Inc. under the partial sponsorship of the Environmental Protection Agency. Work was completed as of March 31, 1973.

CONTENTS

Page

ABSTRACT iv

LIST OF FIGURES ix

LIST OF TABLES x

LIST OF APPENDICES xvi

ACKNOWLEDGEMENTS xvii

Sections

I CONCLUSIONS 1

II RECOMMENDATIONS 3

III INTRODUCTION 4

GENERAL 4

OBJECTIVES 5

TEST LAKES 5

IV FIELD AND ANALYTICAL PROCEDURES 7

MOTOR OPERATION 7

PARAMETERS 9

STATISTICS 9

V WATER CHEMISTRY 12

FIELD AND LABORATORY PROCEDURES 12

RESULTS AND DISCUSSION 14

Dissolved Solids, Conductivity, and Hardness 14

Suspended Solids and Turbidity 14

Chlorida, Fluoride, and Sulfate 14

Iron, Magnesium, and Lead 19

Contents (Continued)

Section Page

V Inorganic Carbon 19

Organic Carbon 25

pH and the Buffering Capacity 25

Dissoved Oxygen and Oxygen Demands 30

Micronutrients (Phosphorus and Nitrogen) 30

SUMMARY 42

VI MACROPHYTES AND ATTACHED ALGAE 44

INTRODUCTION 44

FIELD PROCEDURES 46

RESULTS 46

Species Composition and Distribution 46

Macrophyte Biomass 48

Succession of Macrophytes 55

Grassbed Primary Productivity 55

DISCUSSION 63

Evaluation of Methods 63

Macrophytes 66

Dependent Components 67

Grassbed Productivity 68

Carbon Dioxide Pathways 69

SUMMARY 69

VII PHYTOPLANKTON 74

FIELD AND LABORATORY PROCEDURES 74

RESULTS AND DISCUSSION 75

Contents (Continued)

Section Page

VII Species Composition 75

Indicator Organisms 80

Cell Density 81

Chlorophyll a 84

Phytoplankton Species Diversity 84

Phytoplankton Primary Productivity 87

SUMMARY 90

VIII BENTHIC MACROINVERTEBRATES

FIELD AND LABORATORY PROCEDURES 92

RESULTS AND DISCUSSION 94

Densities 97

Diversity Indices of Benthic Macroinvertebrates 100

SUMMARY 105

IX SENSORY PANEL TEST FOR FISH TAINTING 106

METHODS 106

RESULTS AND DISCUSSION 107

X REFERENCES 111

XI APPENDICES 114

FIGURES

No. Page

1 A cross-section of the vegetation of three test ponds, illustrating the differing macrophyte associations among the epilittoral, eulittoral, sublittoral, and limnetic zones. 45

2 Macrophyte biomass (in liters per square meter) of the shallow-eulittoral zone of three test ponds. 49

3 Macrophyte biomass (in liters per square meter) of the deep-eulittoral zone of three test ponds. 52

4 Macrophyte biomass (in liters per square meter) of the sublittoral zone of three test ponds. 53

5 Total macrophyte biomass (in liters per square meter) of the shallow-eulittoral, deep-eulittoral, and sublittoral zone of the three test ponds. 54

6 Gross productivity of the grassbed community in the sublittoral zone in the three test ponds. 57

7 Periphyton growth rates of the three test ponds, as estimated from growth on glass slides. 64

8 CO_2 carbon materials circuit of the eulittoral zone of the Drainless Engine Pond. 70

9 CO_2 carbon materials circuit of the eulittoral zone of the Drained Engine Pond. 71

10 Phytoplankton primary productivity (g Cm^{-3} day^{-1}) in the surface of the limnetic zone. 88

11 Benthic sampling locations of the test ponds. 93

12 An annual cycle of total macroinvertebrate densities determined for the three test ponds during treatment. 99

13 Diversity indices of the benthos with the chironomids pooled together as one species. 103

14 Diversity indices of the benthos with the chironomids identified to the species level. 104

TABLES

No.		Page
1	Schedule of motor operation.	8
2	Parameters and sampling frequency.	10
3	List of the chemical parameters, sampling sites and analytical methods used.	13
4	Levels of total solids, suspended solids, dissolved solids, conductivity, total hardness, and turbidity of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of the three ponds studied during the first fiscal year.	15
5	Comparisons of the average levels of total solids, suspended solids, dissolved solids, total hardness, conductivity, and turbidity between ponds before treatment and during treatment using pooled sample t-tests and the 95 percent confidence interval.	16
6	Levels of magnesium, iron, chloride, sulfate, and fluoride of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of three ponds studied during the first fiscal year.	17
7	Comparisons of the average levels of magnesium, iron, chloride, sulfate, and fluoride between ponds before treatment and during treatment using pooled sample t-tests and 95 percent confidence interval.	18
8	Lead levels measured in selected samples of water, sediments, and plant and animal tissues that were collected from the Control Pond, Drained Engine Pond, and Drainless Engine Pond before motor operation and during motor operation.	20
9	Total organic carbon levels of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of three ponds studied during the first fiscal year and levels of inorganic carbon including dissolved organic and particulate organic fractions of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of the three ponds studied during the second fiscal year.	22

Tables (Continued)

No.		Page
10	Comparisons of the average levels of organic carbon and inorganic carbon between ponds during treatment using pooled sample t-tests and the 95 percent confidence interval.	23
11	Hydrocarbon levels of surface water samples that were collected before and while the motors were operating from each of the three ponds during January, 1973.	26
12	Dissolved oxygen and pH levels that were measured in the surface layer of the limnetic zone in each of the three ponds studied during the first and second fiscal year.	27
13	Comparisons of the average levels of dissolved oxygen and pH in the surface of the limnetic zone between ponds before treatment and during treatment using pooled sample t-tests and the 95 percent confidence interval.	29
14	Comparisons of the average levels of biochemical and chemical oxygen demand between ponds before treatment and during treatment using pooled t-tests and the 95 percent confidence interval.	31
15	Levels of biochemical and chemical oxygen demands of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of three ponds studied during the first fiscal year.	32
16	Comparisons of average orthophosphorus and total phosphorus levels between ponds during treatment using pooled sample t-tests and the 95 percent confidence interval.	33
17	Comparisons of average orthophosphorus and total phosphorus levels within ponds during treatment using pooled sample t-tests and the 95 percent confidence interval.	33
18	Orthophosphorus and total phosphorus levels of composite water samples that were collected from the grassbed zone and the limnetic zone in each of the three ponds studied during the period of April 4, 1972 to March 28, 1973.	34

Tables (Continued)

No.		Page
19	Comparisons of average nitrate and ammonia levels between ponds during treatment using pooled sample t-tests and the 95 percent confidence interval.	36
20	Comparisons of average nitrate and ammonia levels within ponds during treatment using pooled sample t-tests and the 95 percent confidence interval.	36
21	Levels of nitrate-nitrogen including nitrite-nitrogen for composite water samples that were collected from the grassbed zone and the limnetic zone in each of the three ponds during the time period of April 26, 1972 to March 28, 1973.	37
22	Ammonia-nitrogen levels of composite water samples (surface and bottom water) that were collected from the grassbed zone and the limnetic zone of each of the three ponds during the second fiscal year.	38
23	Comparisons of the average levels of organic nitrogen between ponds before treatment and during treatment using pooled sample t-tests and the 95 percent confidence interval.	39
24	Comparisons of the average levels of organic nitrogen within ponds before treatment and during treatment using pooled sample t-tests and the 95 percent confidence interval.	39
25	Organic nitrogen levels of water samples that were collected from the surface and bottom waters in the limnetic zone in each of the three ponds studied during the first fiscal year and organic nitrogen levels of composite water samples (surface and bottom water) that were collected from the grassbed zone and the limnetic zone for each of the three ponds during the second fiscal year.	40
26	Species, habitat preference, and relative abundances of the common aquatic plants.	47
27	Macrophyte biomass of the shallow-eulittoral, deep-eulittoral, and sublittoral zones of the three test ponds.	50
28	Comparisons of average macrophyte biomass between ponds during treatment using pooled sample t-tests and the 95 percent level of confidence.	51

Tables (Continued)

No.		Page
29	Species composition of macrophytes observed along a 6 meter transect through the eulittoral zones and into the sublittoral zone in Control Pond, Drained Engine Pond, and Drainless Engine Pond during 1972 and 1973.	56
30	Gross primary productivity of the grassbed community measured in duplicate at monthly intervals in the deep-eulittoral zone in each of the three ponds studied during the second fiscal year.	58
31	Comparisons of average grassbed productivity between ponds during treatment using pooled sample t-tests and the 95 percent confidence interval.	59
32	Effects of carbon dioxide enrichment on gross primary productivity in the grassbed communities of the deep-eulittoral zones of the Control Pond on November 2, 1972 and the Drained Engine Pond on October 26, 1972.	60
33	Incident solar radiation and water temperature measured during the carbon enrichment experiments in the Control Pond and the Drained Engine Pond.	61
34	Comparison of grassbed productivity within the Drained Engine and Control Pond before and during carbonate enrichment using two-way ANOVA and the 95 percent confidence interval.	61
35	Periphyton biomass and growth rates of the three test ponds measured during the periods before treatment and during treatment.	62
36	Comparison of average periphyton growth rates between the three test ponds during treatment using one-way ANOVA and pooled sample t-tests (95 percent confidence interval).	65
37	Percent occurrence of blue-green algae within the three test ponds.	76
38	Percent occurrence of green algae within the three treatment ponds	77
39	Percent occurrence of Chrysophyceae in three treatment ponds.	78
40	Percent occurrence of dinoflagellates in three treatment ponds.	78

Tables (Continued)

No. Page

41 Percent occurrence of species of Ciliophora within all plankton samples. 79

42 Summary of plankton species recorded in the Drainless Engine Pond, Drained Engine Pond, and Control Pond during the field investigation. 80

43 Cell densities of composite plankton samples taken from the limnetic zone in each of the test ponds during 1971, 1972, and 1973. 82

44 Comparisons of the standing crops of phytoplankton before and during treatment using one-way ANOVA and pooled sample t-test and the 95 percent confidence level. 83

45 Chlorophyll a levels of composite water samples collected from the limnetic zone of the three ponds during 1971 to 1973. 85

46 Species diversity indices of composite plankton samples taken from the limnetic zone in each of the three test ponds. 86

47 Comparisons of phytoplankton species diversity between ponds using one-way ANOVA and 95 percent confidence level. 87

48 Effects of high levels of engine emissions on phytoplankton productivity in the Drainless Engine Pond reported as CPM of radioactive carbon assimilated, November 30, 1971. 90

49 Relative abundance of chironomids collected in the ponds from August, 1971 through March, 1973. 94

50 Comparisons of average densities, diversities and relative abundances of macroinvertebrates between ponds and stations using pooled t-tests and the 95 percent levels of confidence. 95

51 Relative abundance of tubificids collected from the ponds from August, 1971 through, 1973. 96

52 A checklist of families denoted for the three ponds. 98

53 A comparison of littoral zone macroinvertebrate diversities to limnetic zone macroinvertebrate diversities from August, 1971 through March, 1973. 101

Tables (Continued)

No.		Page
54	Taste scale used by members of the test panel from the University of Florida Food Sciences Laboratory.	106
55	Results of tests comparing the tastes of sunfish and bass between ponds during treatment in 1971.	108
56	Mean taste scores of sunfish and bass during November, 1971.	109
57	Mean taste scores of sunfish and bass during the time period of February to August, 1972.	109

APPENDICES

Section		Page
A	WATER BUDGET	115
	FIELD PROCEDURES	115
	RESULTS	118
	DISCUSSION	118
	SUMMARY	125
B	TREATMENT LEVELS	127
C	SELECTION OF TREATMENT LEVELS	140
	ASSUMPTIONS	140
	CALCULATIONS	140
D	ENGINE DRAINAGE TESTS	144
	METHODS	144
	RESULTS	145
	DISCUSSION	148
E	LIST OF MACROINVERTEBRATES COLLECTED	152
F	TWO-WAY ANOVA TESTING	194
G	PHYTOPLANKTON AND PROTOZOANS COLLECTED	213

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Dr. H. L. Davis was responsible for editing the final report and for investigating primary productivity and water chemistry. Dr. J. D. Bonds and Dr. H. L. Davis were jointly responsible for water quality analysis. Benthic macroinvertebrates were investigated by Mr. T. V. Belanger and macrophytes were studied by Mr. B. C. Pruitt. Dr. J. B. Lackey and Dr. H. D. Putnam investigated phytoplankton. The Food Sciences Department of the University of Florida conducted fish taste tests. Statistical analysis of the data was handled by Dr. H. L. Davis, A. A. Arroyo and Mr. L. D. Haugh.

Appreciation is extended to Mr. Nath Doughtie for allowing the field study to be conducted on his property near Archer, Florida

SECTION I

CONCLUSIONS

1. The phytoplankton in the limnetic zone of the southern test lakes showed some temporal changes in species composition, standing crop, species diversity and primary productivity. These changes were probably due to seasonal variations in temperature, light and nutrient levels, and cannot be conclusively correlated with treatment effects of outboard motor operation.

2. Phytoplankton bioassays conducted in situ on a limited basis show outboard motor exhaust water at a ratio of 1:24 (ratio of exhaust water to lake water) to inhibit photosynthesis. This treatment level is 390 times the exhaust gas water concentration anticipated in waters receiving normal outboard motor usage. It is unrealistic to think that boat usage would reach this level on any recreational lakes.

3. Growth rates and biomass of periphyton cultured in the limnetic zone on artificial substrates were not affected by outboard motor operation in the southern test lakes.

4. In the southern test lakes, distribution, species composition and diversity of benthic macroinvertebrates were not affected by motor operation except in a small area immediately beneath the permanently mounted motors where scouring of bottom sediments resulted from motor operation.

5. Motor operation in the southern lakes increased the concentration of dissolved aromatic hydrocarbons, mixed and circulated the lake water, and therefore distributed the hydrocarbon emissions as well as other emissions throughout the lakes. The concentration of aromatic hydrocarbons increased from background levels of less than 0.01 mg/1 to levels of 1.0 mg/1 during motor operation. When the motors were not operated for two days, hydrocarbon levels declined to less than 0.1 mg/1.

6. The level of dissolved organic carbon in the limnetic zone of the lake treated with drained type engines was significantly greater than both the control lake and the lake treated with drainless type engines. The drainless type engine has a recirculating device which eliminates crankcase drainage. The drained type engine does not have this device and therefore emits a greater amount of unburned fuel.

7. Fish taste studies conducted by the University of Florida Food Sciences Department have demonstrated no evidence of tainting by outboard motor emissions even at treatment levels far in excess of those in the U.S. Public Health Service study where tainting was observed.

8. As a result of background sampling before treatment large amounts of lead (8 to 90 mg Pb/kg of dried plant tissue) were detected in the rooted vegetation of the grassbed community. Therefore, the effects of lead emissions on the southern lakes were not studied.

9. There was no overt evidence that treatment significantly affected the levels of the following chemical parameters; iron, magnesium, chloride, sulfate, fluoride, total solids, suspended solids, dissolved solids, total hardness, conductivity, turbidity, pH, biochemical oxygen demand, and chemical oxygen demand.

10. Except for carbon, there was no direct evidence of differences in the nutrient regimen of the southern lake systems associated with treatment.

11. Outboard motor operation probably increased grassbed productivity in the southern test lakes. The drained engine test lake exhibited a significantly higher (approximately 100 percent) grassbed productivity and biomass than the control lake. The grassbed productivity of the drainless engine lake, although not statistically significant, averaged approximately 8 percent higher than the control lake. Biomass in the control lake and in the drainless engine lake was similar.

12. The effects of outboard motor emissions on the aquatic ecosystem in the southern lakes could not be discerned from the effects of mixing and stirring induced in the lakes by outboard motor operation.

SECTION II

RECOMMENDATIONS

1. An investigation to assess the effect of outboard motor operation on the carbon dioxide budget should be conducted in lakes exhibiting low carbonate alkalinities. Emphasis should be placed on the effects of carbon enrichment on primary productivity and plant biomass and subsequent effects on important higher trophic level organisms. Carbon dioxide pathways (e.g. mass transport of carbon dioxide via water circulation, dissolved carbon dioxide emissions, atmospheric diffusion of carbon dioxide) should be traced and quantified using NDIR gas analysis. Adequate baseline data should be collected, e.g. annual cycle.

2. Experiments should be designed to study the joint effects of motor emissions and mixing and stirring such as those experienced in this study.

3. A study should be conducted to trace and quantify the pathways of hydrocarbon emissions. This study should include assessments of the utilization of hydrocarbon emissions by heterotrophic microorganisms, the release of dissolved hydrocarbon emissions to the atmosphere, and the sorption of dissolved hydrocarbon emissions by suspended particulate matter and bottom sediments.

SECTION III

INTRODUCTION

GENERAL

Outboard engines are one of the many potential sources of water pollution since they are suspected of contributing significant quantities of unburned hydrocarbons, lead, and phenol to the water through their exhaust system. Surber, English, and McDermott (50) have reported that outboard motor exhaust water contains an average of 105 gms/gal of non volatile oil, 57 gms/gal of volatile oil, 0.53 gms/gal of lead, and 0.6 gms/gal of phenol.

However, there is little data available defining the pollution from outboard engines and its effect on the aquatic environment. English, McDermott, and Henderson (12) have demonstrated that fish can become tainted by exposure to water contaminated by outboard motor exhaust. English *et al.*, found that fish tainting occurred in fish confined in live boxes in a motor pond when the daily fuel use exceeded 0.000017% and the cumulative fuel use exceeded 0.00108%.

The California Department of Public Health (4) reported a study to determine the effect of the operation of outboard motors on water quality. Significant increases in chemical oxygen demand, total solids, lead, phenols, oils and grease were noted in laboratory tests. However, these materials were not observed in surface waters at reservoirs where boating was popular. Similar results were found by Putnam and DuBose (39) on a study of Lake X in Florida. On the other hand, Yousef (58) reported that mixing and agitation of the water column as a result of motorboating caused increases in turbidity, organic carbon, particulate organic phosphate, and under certain conditions dissolved oxygen. Yousef's study was conducted in four lakes near Winter Park, Florida, three of which were used for motorboating.

Kuzminski, Ghan, and Roberts (23), conducted bioassays to determine the median lethal concentrations (LD_{50}) of fuel burned to water volumn for bluegills and fathead minnows (*Pimephales promelas*). Outboard engine water was added to aquaria containing the fish to be utilized in the assay. LD_{50} values of 0.29% - 0.37% for bluegills, and 0.14% -0.047% for fathead minnows were obtained by this technique. English, *et. al.* (12) reported LD_{50} for bluegills of 0.040% and LD_{50} for fathead minnows of 0.055%.

At the present time public outcry against pollution is causing much legislation to be passed both on a state and federal level for pollution control. Passage of legislation based on hysteria and not based on adequate technical data can be harmful to certain industries. The boating industry is a perfect example of the potential danger. The Idaho House, on February 27, 1970, passed a bill to require two-cycle marine engines to have anti-pollution devices after January 1, 1972. Similar bills are being presented in other states and may be passed in the near future.

Pollution legislation affecting marine engines must be based on sound technical information. This is essential not only to protect the boating industry but the public because it is the public that in the long run must pay the price of pollution control. The boating industry is willing to do everything possible to limit pollution from marine engines, however, sound technical data must be developed to define the overall problem and its possible effects on the environment.

OBJECTIVES

In April, 1971, the Environmental Protection Agency and the Boating Industry Association funded a study to evaluate effects of engine exhaust on freshwater ecosystems. The research program was designed to examine the impact under two climatic conditions. These were: 1) a subtropical Florida environment, representing a warm water system, and 2) a northern temperate environment, representing a cold water system. This report presents the results of this investigation for southern lakes.

TEST LAKES

An aerial and ground survey covering approximately a three county area in north central Florida was conducted to locate the test sites for the southern field operations. Generally, site selection depended on contiguity of three small lakes, so that they would be reasonably close to one another and located within an area of identical soil type. It was necessary that they be in an isolated area away from roads or any shoreline development, that they have a history of isolation from boating activites; that they range in size from 2-10 acres and be reasonably accessible by trails for sampling; that prevailing water chemistry and aquatic biota be representative of Florida waters.

Three ponds west of Archer, Florida were selected. There were several evident advantages for using the Archer Ponds. These were: 1) their close proximity to Gainesville; 2) their consistence with the small lake concept as required by the Environmental Protection Agency; 3) their oligotrophic tending state; and 4) their natural aquatic systems, which are far superior for research than artificial systems.

The test lakes are located in a sandy terrain with a predominantly Oak-Pine forestation. The physical features of the ponds ideally lend themselves to the investigation since they are small and discrete aquatic systems. The Drainless Engine Pond has a surface area of about 2-3 acres, while the Drained Engine Pond is slightly larger, being approximately 4 acres in size. Both are deep enough to prevent drying even under an extreme drought.

As with many Florida lakes, the shoreline fluctuates seasonally and yearly as influenced primarily by rainfall. Neither of the ponds are connected to the ground water aquifer and therefore can be considered as perched systems. The water budget for both test ponds wholly depends on rainfall and since there are no tributary streams, evaporative loss through solar radiation controls the lake level. Appendix A provides an in-depth discussion of the water budget of the test lakes.

Both the northern and southern lake studies now complete represent the most comprehensive investigation on the effects of outboard engine emissions on natural waters. It is clear, however, that much further research could be carried out to examine long term effects on the biota of lacustrine systems. At the present time, this appears impractical due to limited funding and also to limited sensitivity of methods to measure subtle changes that may occur in the various biological compartments.

SECTION IV

FIELD AND ANALYTICAL PROCEDURES

MOTOR OPERATION

Treatment levels selected for the study conducted on engine operation represented a level three times greater than the normal inland water boating usage (Actual treatment levels are presented in Appendix B). The essential parameter, in terms of treatment levels, was the amount of fuel burned per unit water per unit time. Identical pairs of outboard engines (drained and drainless) burned 5.4 gallons of fuel per day, 5 days a week throughout the study period. How this level of fuel was selected, and the treatment level it represented, is discussed in Appendix C.

Appendix D contains the results of engine drainage testing performed upon the outboard motors utilized in the southern lake study.

Leaded fuel (Amoco #30) was used in both test ponds throughout the study and mixed in a 50 to 1 gas to oil ratio. The oil was Mercury Quicksilver 50 to 1 oil. The treatment was conducted such that matched pairs of engines were run simultaneously, i.e., a drainless engine of given horsepower and manufacture was operated at the same throttle setting and at the same time as a drained engine of identical specification. Table 1 gives a schedule of engine operation followed through the course of the project.

All engines were equipped with test propellers to insure that engine loadings under static running conditions were similar to those experienced under normal boating usage. Throughout the 75 weeks that the treatment was conducted, a total of approximately 1900 operating hours were logged in each test pond. The fuel consumed totalled about 2000 gallons per pond. The engines were run for one out of every four days at 1/4 throttle and the remainder at 3/4 throttle.

The engines were mounted on the end section of docks constructed at each of the test ponds. These end sections were fitted with pontoons which allowed the section to rise or fall with the fluctuating water level. The docks were sufficiently long to insure that the engines remained in water greater than five feet deep at all times throughout the project. Each engine was equippped with a running time meter. The engines were started with 5.4 gallons of fuel in their tank and allowed to run unattended until the fuel supply was exhausted.

During motor operation the test propellers caused limited circulation within the pond. Standard propellers would have moved considerably more water, but due to the small size of the test ponds this would not have represented a normal boating effect. Even so, the limited

Table 1. Schedule of motor operation.

1971	MOTORS[a]	1972	MOTORS[a]	1973	MOTORS[a]
October	9.8 HP Mercury	January	9.9 HP Chrysler	January	35 HP Chrysler
November	9.8 HP Mercury	February	6 HP OMC	February	18 HP OMC
December	9.8 HP Mercury	March	9.9 HP Chrysler	March	35 HP Chrysler
		April	6 HP OMC		
		May	9.9 HP Chrysler		
		June	18 HP OMC		
		July	35 HP Chrysler		
		August	18 HP OMC		
		September	35 HP Chrysler		
		October	18 HP OMC		
		November	35 HP Chrysler		
		December	18 HP OMC		

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[a] Matched pairs of drainless and drained motors were operated 5 days per week on 5.4 gallons of Amoco #30 fuel per day.

circulation resulting from motor operation transported materials e.g. nutrients, dissolved gases, and engine emissions, throughout the pond within a short period of time (less than one day).

PARAMETERS

Water quality, water quantity, and biological components were monitored in the three test ponds during the baseline study (summer, 1971) and the 18 month long field investigation (October 18, 1971 to March 31, 1973) (Table 2). The frequency of sample collection ranged from weekly measurements to quarterly sampling depending on the parameter, their natural variability, and other restraints. Standard routine procedures were employed during field collection and laboratory analysis. Descriptions of sampling and analytical procedures including frequency, replication, station locations are provided in each of the following sections of this report.

STATISTICS

Parametric statistical tests were used to analyze and interpret the chemistry and biology data. One-way ANOVA, linear regression and pooled sample *t* tests (47) were performed to determine if there were any overt differences between ponds or within ponds that could be attributed to treatment with outboard engines. Supplemental two-way ANOVA tests (2) were performed to determine differences caused by motor operation that could be a function of the season of year as well as to confirm the results of the previous tests showing a possible treatment effect. Appendix F presents the results of the two-way analysis.

Table 2. Parameters and sampling frequency

Parameter	Sampling Frequency
Water Quality Parameters	
Phosphate	Monthly
Nitrate	Monthly
Ammonia	Monthly
Organic Nitrogen	Monthly
Organic Carbon	Monthly
Inorganic Carbon	Monthly
BOD and COD	Monthly
Chloride	Bimonthly to Monthly
Fluoride	Bimonthly to Monthly
Sulfate	Bimonthly to Monthly
Iron	Bimonthly to Monthly
Magnesium	Bimonthly to Monthly
Hardness	Bimonthly to Monthly
Conductivity	Bimonthly to Monthly
Turbidity	Bimonthly to Monthly
Solids	Bimonthly to Monthly
pH	Bimonthly to Monthly
Dissolved Oxygen	Weekly
Aromatic Hydrocarbon	Biweekly
Lead	
Water Quantity Parameters	
Rainfall	Biweekly
Evaporation	Weekly
Water Level	Weekly
Biological Parameters	
Macrophytes	Seasonal
Species Composition	
Biomass	
Distribution (temporal and spatial)	
Phytoplankton	Monthly
Species Composition	
Population Sizes	
Species Diversity Index	
Distribution (temporal)	
Chlorophyll a	
Primary Production	

Table 2. Continued

Parameter	Sampling Frequency
Biological Parameters (cont'd)	
Benthic Macroinvertebrates	Monthly
Species Composition	
Population Sizes	
Species Diversity Index	
Distribution (temporal and spatial)	
Grassbed Community (gross) Primary Productivity	Monthly

SECTION V

WATER CHEMISTRY

The availability of nutrients, carbon dioxide, and oxygen have a direct bearing on the productivity of lower trophic level organisms which, in turn, controls the population size and biomass of organisms at the top of the food chain (31). Under enriched conditions, these life forms are likely to increase in population density and individual biomass; however, they may decrease under nutrient limiting or stressed conditions. Chemicals such as oil, lead, and phenol which occur in outboard motor emissions may cause such stressed conditions.

Thus a knowledge of the levels of the chemical constituents in an aquatic system, their rates of change, their sources, and their uses is important in defining the condition of that particular system. Keeping these interrelationships in mind, the dynamics of the chemical system in the treatment lakes were examined while being treated by outboard engine operation.

FIELD AND LABORATORY PROCEDURES

The chemistry of the test lakes was assessed using recognized standard analytical techniques. These included procedures outlined in the 13th edition of *Standard Methods for the Examination of Water and Wastewater* (46) as well as those recommended by Strickland and Parsons (49).

Frequency of sampling depended upon the various individual constituents and was conducted at weekly and at monthly intervals. Sampling schedules were modified from time to time during the study based on data evaluation. These changes were generally the result of conferences with the EPA project officer and other members of his technical staff.

Acquisition of baseline data was carried out from July through mid-October of 1971. This abbreviated period was sufficient to characterize the pond chemistry since, for practical purposes, they were similar to other acid soft water lakes in Putnam County, Florida. The latter have been extensively studied and described by Brezonik *et al.* (3), Putnam *et al.* (31).

Generally, samples were composites of surface and subsurface water collected either with non-metallic Van Dorn or Kemmerer equipment. Almost without exception samples were stored in 5 liter pyrex reagent bottles at 0°C. Analyses were usually completed within 24 hours of collection. The following table summarizes the chemical parameters, methods of analysis and limits of detection used in this study (Table 3).

Table 3. List of the chemical parameters, sampling sites and analytical methods used.

Constituent	Sampling Site(s)[a]	Methods	Limits of Detection mg/1	Reference[f]
Phosphorus	C(GB), C(LZ)	Ascorbic Acid	0.001	Strickland and Parsons (49)
NO_3-N	C(GB), C(LZ)	Brucine sulfate	0.010	*Standard Methods* (46)
NH_3-N[g]	C(GB), C(LZ)	Hypochlorite oxidation	0.001	Strickland and Parsons (49)
Org-N	S(SW), B(LZ), C(GB), C(LZ)	Macro-kjeldahl	0.010	*Standard Methods* (48)
Organic Carbon[b]	C(LZ)	Total Carbon Analyzer	0.1	Beckman (m)[h]
Inorganic Carbon[c]	C(LZ)	Total Carbon Analyzer	0.1	Beckman (m)[h]
BOD	C(LZ)	5-day	0.5	*Standard Methods* (46)
COD	C(LZ)	Dichromate reflux	5.0	*Standard Methods* (46)
Cl	C(LZ)	Specific ion	5.0	*Standard Methods* (46)
SO_4	C(LZ)	Turbidimetric	0.005	*Standard Methods* (46)
Fe	C(LZ)	Atomic Absorption	0.002	Perkin-Elmer (m)
Mg	C(LZ)	Atomic Absorption	0.001	Perkin-Elmer (m)
Hardness	C(LZ)	EDTA-titration	5.0	*Standard Methods* (46)
Conductivity	C(LZ)	Conductance meter	--	Labline (m)
Turbidity	C(LZ)	Turbidimeter	0	Hellige (m)
Solids	C(LZ)	Gravimetric	0.005	*Standard Methods* (46)
pH	C(LZ)	Glass electrode	--	Orion (m)
DO	C(LZ)	Polarographic	--	YSI (m)
Pb[d]	C(LZ)	Atomic Absorption	0.001	Perkin-Elmer (m)
F	C(LZ)	Specific ion electrode	0.5	Orion (m)
Aromatic Hydrocarbons	S(LZ)[e]	Cyclohexane extraction	0.5	Dept. Mech. Eng. Univ. of Michigan

[a] Abbreviations: C = Composite; S = Surface; B = Bottom; LZ = Limmetic Zone; GB = Grassbed.

[b] A 0.30μ porosity. Gelman GF filter was used to separate the particulate fractions from the dissolved fractions.

[c] Preserved in a saturated solution of $HgCl_2$.

[d] Measurements also of dried plant and animal tissues.

[e] Beside motor and on opposite side of pond.

[f] Manufacturer (m)

[g] Ammonia-nitrogen plus amino acid-nitrogen (available to many phytoplankers)

[h] Strickland and Parsons (49) reports limit of detection at 0.09 mg/1 (dissolved organic carbon).

RESULTS AND DISCUSSION

Dissolved Solids, Conductivity, and Hardness

Soft water was found to be characteristic of the three ponds as shown by the low levels of dissolved solids, conductivity, and total hardness presented in Table 4. No significant differences for the three parameters were found between the ponds during the baseline period before treatment (5/01/71 to 10/13/71) or during the first two months of treatment (10/13/71 to 1/04/72). Arithmetic means of the levels of dissolved solids ranged from 33.5 mg/1 in the Drainless Engine Pond to 36.9 mg/1 in the Drained Engine Pond before treatment. A general decline of approximately one-third was observed during treatment as the mean levels of dissolved solids ranged from 18.5 mg/1 in the Drained Engine Pond to 22.7 mg/1 in the Control Pond. Conductivites exhibiting an overall range of 23.8 to 28.9 μmhos averaged about the same before treatment as during treatment. The average levels of total hardness in all three ponds ranged from 5.4 to 6.5 mg/1 before treatment and 4.2 to 4.7 mg/1 during treatment. This represented a 20% decline during the fall season.

Suspended Solids and Turbidity

All three ponds had low levels of suspended solids and turbidity (Table 4). As summarized in Table 5, no significant differences for these parameters were noted between the three ponds before or during treatment. Both suspended solids and turbidity declined in all three ponds during the fall and early winter primarily as a result of reduced biological activity and surface runoff. Averages of suspended solids in the three ponds ranged 8.6 to 12.6 mg/1 during the summer of 1971 and declined to averages of 1.9 to 4.3 mg/1 as treatment was initiated. Since no differences were noted between ponds, these changes are attributed to natural trends instead of treatment. Similarly, turbidity during the fall season was lower than during the summer. A comparison of mean values show a range of 1.7 to 2.1 mg/1 during the fall and 2.3 to 2.7 mg/1 during the summer.

Chloride, Fluoride, and Sulfate

As is expected in soft water lakes, low levels of chloride (~ 2 mg/1), fluoride (~ 10 μg/1), and sulfate (~ 3 mg/1) were observed in the Archer ponds (Table 6). Using t-tests and the 95% confidence interval, no significant differences in these anions were found among the three ponds before treatment or during treatment (Table 7). In general, the averages presented in Table 6 show that chlorides and sulfates declined but fluorides increased during the fall.

Table 4. Levels of total solids, suspended solids, dissolved solids, conductivity, total hardness, and turbidity of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of the three ponds studied during the first fiscal year.

CHEMICAL PARAMETERS[a,c]

	Drainless Engine Pond						Drained Engine Pond						Control Pond					
Date	Total Solids (mg/l)	Susp. Solids (mg/l)	Dis. Solids (mg/l)	Total[b] Hard (mg/l)	Cond. (μmhos)	Turb.[c] (mg/l)	Total Solids (mg/l)	Susp. Solids (mg/l)	Dis. Solids (mg/l)	Total[b] Hard (mg/l)	Cond. (μmhos)	Turb.[c] (mg/l)	Total Solids (mg/l)	Susp. Solids (mg/l)	Dis. Solids (mg/l)	Total[b] Hard (mg/l)	Cond. (μmhos)	Turb.[c] (mg/l)
5/01/71	27	17.0	nm	nm	27.0	1.86	38	13.0	nm	nm	31.0	2.72	55	14.0	nm	nm	30.0	1.80
7/28/71	60	27.0	33.0	5.6	37.0	13.00	102	25.0	77.0	4.8	58.0	8.00	120	62.0	58.0	5.2	37.0	8.00
8/17/71	30	6.0	24.0	6.0	24.3	2.80	26	6.0	20.0	4.3	26.9	2.40	46	12.0	43.0	5.6	41.0	2.80
8/25/71	28	4.0	24.0	4.0	21.0	1.05	39	6.0	33.0	3.6	23.0	1.15	43	4.0	39.0	4.0	27.3	2.00
9/03/71	14	2.0	12.0	3.7	36.7	0.80	12	5.0	7.0	3.4	26.9	0.80	19	4.0	15.0	4.4	31.6	2.10
9/10/71	21	1.0	20.0	6.4	23.2	1.20	16	1.0	15.0	8.0	22.9	4.00	19	1.0	18.0	6.8	30.1	2.10
9/15/71	43	5.0	38.0	5.6	18.5	1.80	39	10.0	29.0	6.2	17.3	4.00	39	5.0	34.0	9.6	33.5	1.20
9/22/71	32	8.0	56.0	5.6	19.0	1.20	70	7.0	63.0	4.8	18.0	2.50	64	11.0	21.0	3.2	21.0	1.60
9/29/71	63	4.0	59.0	7.2	16.0	0.75	76	5.5	71.5	12.8	18.0	0.75	64	6.0	58.0	12.0	21.0	1.40
10/06/71	21	2.5	18.5	6.0	19.5	2.30	23	3.5	19.5	8.0	18.5	1.20	22	2.5	19.5	10.8	24.0	0.90
10/13/71	68	18.0	50.0	3.6	19.2	1.90	52	17.0	34.0	3.4	21.2	1.90	51	17.0	34.0	3.4	21.0	2.00
10/20/71	16	2.5	13.0	nm	21.0	1.20	16	7.5	8.0	nm	nm	1.20	18	2.5	15.0	nm	18.0	1.12
11/11/71	5	3.0	2.0	nm	36.0	0.45	7	6.0	1.0	nm	25.0	0.15	5	4.0	1.0	nm	28.0	0.15
11/17/71	43	1.0	42.0	2.6	23.0	1.12	32	2.0	30.0	3.0	25.0	1.10	47	3.0	44.0	3.6	28.0	0.51
12/02/71	18	2.0	16.0	2.8	18.0	3.00	17	4.0	13.0	3.8	20.0	5.50	22	5.0	17.0	3.6	25.0	6.50
12/15/71	20	2.0	18.0	4.2	24.0	2.50	16	3.0	13.0	3.6	29.0	2.70	23	4.0	19.0	5.0	28.0	2.70
1/04/72	38	1.0	37.0	7.2	36.0	1.60	49	3.0	46.0	6.8	32.0	1.70	41	1.0	40.0	6.4	38.0	1.50
Baseline Mean	37	8.6	33.5	5.4	23.8	2.61	45	9.0	36.9	5.9	25.6	2.67	49	12.6	34.0	6.5	28.9	2.35
Treatment Mean	23	1.9	21.3	4.2	26.3	1.65	23	4.3	18.5	4.3	26.2	2.06	26	3.3	22.7	4.7	27.5	2.08

[a] Analyses were performed according to the procedures outlined in the 13th edition of Standard Methods (46)

[b] Total hardness is reported as mg/l as $CaCO_3$.

[c] Abbreviations: nm = not measured

Table 5. Comparisons of the average levels of total solids, suspended solids, dissolved solids, total hardness, conductivity, and turbidity between ponds before treatment and during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Parameter	Time Interval[a]	Significance
Ho: Drainless Engine Pond = Control Pond	Total Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Suspended Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Suspended Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Suspended Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Suspended Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Suspended Solids	BT, 5/01/71 to 10/06/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Suspended Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Dissolved Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Dissolved Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Dissolved Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Dissolved Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Dissolved Solids	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Dissolved Solids	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total Hardness	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total Hardness	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Hardness	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Hardness	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Hardness	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Hardness	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Conductivity	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Conductivity	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Conductivity	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Conductivity	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Conductivity	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Conductivity	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Turbidity	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Turbidity	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Turbidity	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Turbidity	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Turbidity	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Turbidity	DT, 10/13/71 to 1/04/72	N.S., accept Ho

[a] **Abbreviations: BT = Before Treatment**
DT = During Treatment

Table 6. Levels of magnesium, iron, chloride, sulfate, and fluoride of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of the three ponds studied during the first fiscal year.

	Chemical Parameters[a,b]														
	Drainless Engine Pond					Drained Engine Pond					Control Pond[a]				
Date	Mg (mg/l)	Fe (mg/l)	Cl^- (mg/l)	$SO_4^=$ (mg/l)	F^- (µg/l)	Mg (mg/l)	Fe (mg/l)	Cl^- (mg/l)	$SO_4^=$ (mg/l)	F^- (µg/l)	Mg (mg/l)	Fe (mg/l)	Cl^- (mg/l)	$SO_4^=$ (mg/l)	F^- (µg/l)
05/01/71	0.31	0.07	4.50	nm	nm	0.38	0.08	5.40	nm	nm	0.47	0.13	5.10	nm	nm
07/28/71	nm	nm	4.00	10.00	1.8	nm	nm	4.00	6.00	2.3	nm	nm	1.00	6.00	4.4
08/17/71	nm	0.30	4.00	7.00	1.5	nm	0.30	3.00	6.00	3.0	nm	2.10	2.00	7.00	3.0
08/25/71	0.40	1.00	4.28	3.75	2.8	0.42	0.30	4.18	4.40	2.6	0.51	0.90	2.84	5.30	3.0
09/03/71	nm	0.20	3.30	4.10	2.5	nm	0.20	8.10	2.90	2.4	nm	0.10	6.70	5.60	2.3
09/10/71	nm	0.10	10.00	3.30	3.8	nm	0.10	3.20	4.50	3.4	nm	0.20	3.80	3.90	3.9
09/15/71	nm	0.20	3.40	3.60	3.1	nm	0.20	3.30	5.30	3.0	nm	0.10	1.90	4.50	3.0
09/22/71	nm	0.18	nm	nm	2.8	nm	0.22	nm	nm	2.4	nm	0.18	nm	nm	1.6
09/29/71	0.38	0.08	0.57	3.10	10.0	0.42	0.08	0.63	5.00	0.5	0.49	0.10	0.95	4.10	10.0
10/06/71	0.32	0.28	0.95	3.00	7.5	0.32	0.35	0.62	4.10	7.2	0.44	0.20	1.10	5.00	9.5
10/13/71	0.59	nm	0.57	3.40	9.1	0.69	nm	0.63	5.00	6.0	0.51	nm	0.95	4.10	8.0
10/20/71	0.36	0.70	0.90	2.00	9.0	0.35	0.40	0.95	2.60	9.0	0.42	0.90	0.95	3.80	9.0
11/11/71	0.38	0.80	0.98	2.30	11.0	0.40	0.40	0.63	2.60	9.5	0.36	0.80	0.63	2.60	12.0
11/17/71	0.04	1.00	0.46	2.50	14.5	0.04	3.60	0.45	2.50	15.0	0.05	2.30	0.25	2.70	50.0
12/02/71	0.06	0.50	3.50	nm	1.0	0.08	0.30	3.50	nm	45.0	0.09	0.30	3.80	nm	78.0
12/15/71	0.04	0.20	3.50	0.75	1.2	0.04	0.10	29.40	0.50	1.5	0.05	0.15	6.70	0.70	2.5
01/04/72	0.38	0.40	0.56	0.50	2.7	0.32	0.45	0.56	0.50	3.0	0.38	0.50	0.55	0.50	3.3
Baseline Mean	0.40	0.27	3.56	4.58	4.49	0.45	0.20	3.31	4.80	3.28	0.48	0.45	2.63	5.06	4.87
Treatment Mean	0.21	0.60	1.65	1.61	6.57	0.21	0.88	5.92	1.74	13.83	0.23	0.83	2.15	2.06	25.80

[a] Analyses were performed according to the procedures outlined in the 13th Edition of Standard Methods (46)

[b] Abbreviation: nm = not measured.

Table 7. Comparisons of the average levels of magnesium, iron, chloride, sulfate, and fluoride between ponds before treatment and during treatment using pooled sample t-tests and the 95 percent confidence interval.

Null Hypothesis (Ho)	Parameter	Time Interval[a]	Significance
Ho: Drainless Engine Pond = Control Pond	Magnesium	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Magnesium	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Magnesium	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Iron	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Iron	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Iron	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Iron	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Iron	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Iron	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Chloride	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Chloride	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Chloride	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Chloride	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Chloride	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Chloride	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Sulfate	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Sulfate	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Sulfate	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Sulfate	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Sulfate	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Sulfate	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Fluoride	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Fluoride	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Fluoride	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Fluoride	DT, 10/13/71 to 1/04/72	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Fluoride	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Fluoride	DT, 10/13/71 to 1/04/72	N.S., accept Ho

[a] Abbreviation: BT = Before Treatment
DT = During Treatment

Iron, Magnesium, and Lead

Lead data for macrophytes, fish and sediments are given by Table 8. Due to the unusually high ambient concentrations present, duplicated sediment and macrophyte samples were periodically sent to two independent laboratories for quality assurance measures (Harmon, White, and Associates, Inc., and the Ethyl Corporation). The lead concentrations obtained by these laboratories correlated closely to the values obtained by Environmental Science and Engineering, Inc. Definite trends have not been established which can be directly attributed to increased lead concentrations derived from petroleum fuels. Consequently, treatment was changed from emissions of non-leaded fuels versus leaded fuels to emissions from drained engines versus drainless engines.

The amounts of lead in the water column of all three ponds were similar, as they ranged less than 2 mg/1. In the sediments, concentrations of 1-2 mg/kg were also similar in each pond but ranged an order of magnitude higher than those in the water column. Lead levels in fish tissues were even higher, ranging from 1 to 7 mg/kg and showed no large differences between ponds. The highest concentrations of lead were measured in various species of rooted macrophytes. These levels ranged from 8 to 90 mg/kg of dried plant tissue and showed no differences between the ponds. The macrophyte, Scirpus contained the greatest amounts of lead in all ponds.

Magnesium and iron levels in the water column showed no significant differences at the 95% level of confidence, although the two parameters exhibited opposite temporal trends (Table 6 and 7). During the first six months of the study, the overall averages were about 0.5 mg/1 of iron and 0.3 mg/1 of magnesium.

Inorganic Carbon

The major form of total inorganic carbon in the test ponds is dissolved inorganic carbon which occurs primarily as carbon dioxide and which has been considered in this study to be a limiting factor to primary production.

Mean total inorganic carbon concentrations in the treated ponds were 50 to 66 percent higher than in the Control Pond, although the levels observed in all three ponds fell within the 0.2 to 1.4 mg/1 range (Table 9). These levels are at or near the limit of detection of the analytical method employed and this must be kept in mind when attaching significance to the data and the following interpretation.

Statistical evaluations using pooled sample t-tests showed significant differences (3/06/72 - 3/22/73) between Control Ponds and Drained and Drainless Engine Ponds (Table 10). Control Pond had lower total inorganic carbon levels than either the Drained or Drainless Engine Ponds.

Table 8. Lead levels measured in selected samples of water, sediments, and plant and animal tissues that were collected from the Control Pond, Drained Engine Pond, and Drainless Engine Pond before motor operation and during motor operation.

		Lead Level (mg/kg)^{a,c}		
Substance	Date	Drainless Engine Pond	Drained Engine Pond	Control Pond
Water ^{b}	7-28-71	0.1	<0.1	<0.1
	8-17-71	0.1	<0.1	0.1
	11-11-71	1.7	0.5	0.5
Sediment	6-23-71	1	nm	nm
	7-20-71	nm	2	nm
	7-22-71	nm	nm	2
	9-08-71	1	1	1
	9-22-71	1	1	1
	11-09-71	<1	<1	<1
Plant Tissue:				
Scirpus	7-20-71	nm	39	nm
	7-27-71	nm	nm	90
	9-24-71	nm	13	40
	12-02-71	nm	nm	40
	12-09-71	40	nm	nm
Hydrotrida	7-27-71	nm	35	45
	11-24-71	nm	23	nm
Leersia	7-27-71	nm	nm	24
	9-24-71	8	11	13
	11-06-71	nm	23	nm
	11-24-71	16	nm	nm
	12-09-71	16	nm	nm
Nuphar	7-27-71	nm	nm	15
	9-24-71	11	17	21
	11-24-71	nm	23	nm
	12-02-71	nm	nm	33
	12-09-71	26	nm	nm
	12-30-71	nm	nm	35

Table 8. Continued

		Lead Level (mg/kg)[a]		
Substance	Date	Drainless Enigne Pond	Drained Engine Pond	Control Pond
Animal Tissue:				
Lepomis sp.	8-25-71	<1,<1	<1,<1	nm
	12-17-71	1	1	1
Micropterus salmoides	8-25-71	<1,<1	nm	nm
Fundulus lineolatus	9-29-71	2	3	1
Gambusia affinis	9-29-71	7	nm	nm

[a] Lead levels of plant and animal tissues are based on dry weight of substance; method of analyses involved the use of a Perkin-Elmer atomic absorption spectrophotometer.

[b] Water samples were collected as composites of the surface and bottom layers from the limnetic zone in each of the three ponds.

[c] Not Measured (nm)

Table. 9 Total organic carbon levels of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of the three ponds studied during the first fiscal year and levels of inorganic carbon including dissolved organic and particulate organic fractions of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of the three ponds studied during the second fiscal year.

Date	Oxygen Demands (mg/l)											
	Drainless Engine Pond				Drained Engine Pond				Control Pond			
	TOC	DOC	POC	TIC	TOC	DOC	POC	TIC	TOC	DOC	POC	TIC
9-29-71	12.5	nm	nm	nm	8.5	nm	nm	nm	10.3	nm	nm	nm
10-13-71	5.5	nm	nm	nm	6.5	nm	nm	nm	7.8	nm	nm	nm
11-11-71	7.3	nm	nm	nm	13.4	nm	nm	nm	7.9	nm	nm	nm
12-09-71	11.3	nm	nm	nm	15.6	nm	nm	nm	nm	nm	nm	nm
1-04-72	3.9	nm	nm	nm	6.5	nm	nm	nm	5.0	nm	nm	nm
1-27-72	3.6	nm	nm	nm	4.4	nm	nm	nm	5.4	nm	nm	nm
2-10-72	3.0	nm	nm	nm	4.8	nm	nm	nm	4.5	nm	nm	nm
3-06-72	5.1	nm	nm	0.5	8.6	nm	nm	0.5	8.2	nm	nm	0.3
4-10-72	7.0	5.8	1.2	0.5	7.7	7.1	0.6	0.6	5.2	3.8	1.4	0.6
6-02-72	4.1	4.0	0.1	0.8	6.5	nm	nm	1.3	5.1	4.9	0.2	0.8
6-02-72	3.4	nm	nm	0.4	5.6	5.6	0.1	0.6	4.0	nm	nm	0.3
7-07-72	4.4	3.0	1.4	0.5	6.1	5.3	0.7	1.0	4.4	4.0	0.4	0.4
8-01-72	4.5	4.1	0.4	0.8	6.4	6.3	0.1	1.0	5.3	5.1	0.2	0.5
9-05-72	8.0	7.6	0.4	0.3	8.0	7.4	0.6	0.5	8.3	7.4	0.9	0.3
10-06-72	5.7	nm	nm	0.9	5.6	5.2	0.4	1.0	5.6	4.8	0.8	0.4
10-30-72	5.9	5.5	0.4	1.4	6.8	6.4	0.4	1.0	10.8	6.6	4.2	0.5
11-30-72	5.3	nm	nm	0.4	5.9	nm	nm	0.4	5.1	nm	nm	0.4
12-20-72	4.8	nm	nm	0.5	6.1	nm	nm	0.3	4.7	nm	nm	0.4
1-29-73	5.2	4.9	0.3	1.0	7.8	7.5	0.3	0.7	4.0	3.8	0.2	0.2
2-26-73	5.2	4.5	0.7	0.5	7.5	7.1	0.4	0.5	5.0	nm	nm	0.5
3-22-73	5.3	4.9	0.4	0.8	7.3	nm	nm	0.8	14.8	4.7	nm	0.5
Treatment Mean	5.8	4.9	0.6	0.7	7.4	6.4	0.4	0.7	6.3	5.0	1.0	0.4

Abbreviations: TOC = total organic carbon; DOC = dissolved organic carbon; POC = particulate organic carbon; TIC = total inorganic carbon; nm = not measured.

Table 10. Comparisons of the average levels of organic carbon and inorganic carbon between ponds during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Parameter	Time Interval	Significance
Ho: Drainless Engine Pond = Control Pond	Total Inorganic Carbon	3/06/72 to 3/22/73	.05, reject Ho; Drainless > Control
Ho: Drained Engine Pond = Control Pond	Total Inorganic Carbon	3/06/72 to 3/22/73	.05, reject Ho; Drained > Control
Ho: Drainless Engine Pond = Drained Engine Pond	Total Inorganic Carbon	3/06/72 to 3/22/73	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Dissolved Organic Carbon	3/06/72 to 3/22/73	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Dissolved Organic Carbon	3/06/72 to 3/22/73	.05, reject Ho; Drained > Control
Ho: Drainless Engine Pond = Drained Engine Pond	Dissolved Organic Carbon	3/06/72 to 3/22/73	.05, reject Ho; Drained > Drainless
Ho: Drainless Engine Pond = Control Pond	Particulate Organic Carbon	3/06/72 to 3/22/73	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Particulate Organic Carbon	3/06/72 to 3/22/73	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Particulate Organic Carbon	3/06/72 to 3/22/73	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total Organic Carbon	3/06/72 to 3/22/73	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Organic Carbon	33/06/72 to 3/22/73	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Organic Carbon	3/06/72 to 3/22/73	.05, reject Ho; Drained > Drainless
Ho: Drainless Engine Pond = Control Pond	Total Organic Carbon	10/31/71 to 3/22/73	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Organic Carbon	10/31/71 to 3/22/73	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Organic Carbon	10/31/71 to 3/22/73	.05, reject Ho; Drained > Drainless

Additional statistical analyses were employed to determine the separate and (possibly) interactive effects of monthly or seasonal climatic conditions and treatments on the level of inorganic carbon. Table F1 gives the mean TIC levels for each season and treatment (Appendix F). Tables F2 and F3 summarize the results of two-way analyses of variance in which months and seasons, respectively, are used to represent temporal effects. In both cases no interaction of these temporal variables with treatments was found. In addition, no overall significant differences were found in TIC for the different months (or seasons). This was not unexpected since the TIC measurements were made in the centers of each pond, where normal community respiration and production rates are low and near atmospheric equilibrium conditions of CO_2 prevail.

The results in Table F3 further indicate that there are significant differences among treatments (97 percent confidence level), after controlling for possible seasonal effects. The Control Pond had a significantly lower average level (0.4 mg/l) than either of the two treated ponds (0.7 mg/l), as already established in the one-way analyses of variance suggesting that engine emissions elevated the level of total inorganic carbon in the limnetic zone.

The rate of CO_2 input through engine emissions can be estimated from empirical equations derived by the Department of Mechanical Engineering of the University of Michigan (Vande Steeg, personal communication). By using these equations, it was estimated that 20% of the gasoline is oxidized to CO_2 during the operation of an outboard motor. Assuming that all of the CO_2 is uniformly distributed and remains in the ponds, the operation of outboard motors during 1972 provided an average input of 0.14 g C/M^3 per day. This is equivalent to one-fifth of the ambient CO_2 level. Because of diffusion and solubility characteristics there will be a portion of the exhaust lost to the atmosphere. However, a continuous CO_2 input even though losses to the atmosphere occur, would be expected to elevate the ambient CO_2 level. Thus, the CO_2 emissions would have the potential for increasing primary productivity in a CO_2 limited zone should there be adequate water circulation.

As previously mentioned, carbon dioxide limiting conditions may exist at times in the test ponds, especially after midday in the shallow grassbed zone when there has been a high rate of sustained net plant production. Rates of 0.3 g C/M^3 per hour are typcial in these grassbeds during the summer growing season. In comparison, the natural levels of inorganic carbon are low ranging from 0.2 to 1.4 g C/M^3 (Table 9). As a result carbon limiting conditions are likely to occur during the summer; however, carbon limiting conditions are not likely to occur during the dormant season (winter) or in the unproductive limnetic zone since the rate of sustained plant production is low (<0.05 g C/M^3 per hour). Therefore, the rates of CO_2 diffusion and transport into a carbon limited area constitute an important aspect in defining the effects of outboard motor emissions.

Two natural phenomena provide significant inputs of CO_2 in the test lakes. First, CO_2 from the air diffuses into the ponds as the pCO_2 in the pond declines below the atmospheric pCO_2. Diffusion rates may be as high as 1.15 g C/M^2 per day (14, 15). A second natural source of CO_2 is community respiration. Other sources of CO_2 may be supplied through the operation of outboard motors. These include CO_2 exhaust emissions and transport of waters containing CO_2 to the carbon limited zone.

Organic Carbon

Total organic carbon levels were significantly higher in the Drained Engine Pond than in the Drainless Engine Pond (Table 10). A mean concentration of 7.4 mg/l in the Drained Engine Pond was 22% higher than that of the Drainless Engine Pond and 15% higher than the Control Pond. This is attributed to the crankcase drainage associated with the use of draintype engines. Dissolved organic carbon (D.O.C.) was also significantly higher in the Drained Engine Pond (mean 6.4 mg/l) than in the Drainless Engine Pond (mean 4.9 mg/l) as well as higher than in the Control Pond (mean 5.0 mg/l).

Some difficulty is encountered in interpreting the D.O.C. data since a study of the aromatic fraction, revealed higher levels in the Drainless Engine Pond (mean residual level of 0.23 mg/l as toluene) than in the Drained Engine Pond (mean residual 0.16 mg/l) or in the Control Pond (mean 0.005 mg/l) (Table 11). There are several ways in which this apparent discrepancy can be explained, the most likely of which involves the degradation of insoluble hydrocarbon emissions to soluble metabolites which increase the dissolved organic carbon level while not affecting the aromatic hydrocarbon levels. Since no complete characterization of the organic species in the water column was attempted, explanations of this type are only speculative.

Other trends in the aromatic hydrocarbon data (Table 11) show that dispersion is throughout the ponds and that the aromatics do not persist as a dissolved fraction in the water column much longer than two days following motor operation.

pH and The Buffering Capacity

As seen from the data in Table 12 the three ponds exhibited acid conditions throughout the year and narrow pH ranges (4 to 6). The Drainless Engine Pond had the widest pH range of 3.65 to 5.70 and the Drained Engine Pond had the narrowest range of 4.11 to 5.62. Control Pond exhibited the highest pH range of 4.25 to 5.95. No significant differences were found between the three ponds before treatment or during treatment indicating that there was no measurable effect of engine emissions on the level of pH (Table 13).

Table 11. Hydrocarbon levels of surface water samples that were collected before and while the motors were operating from each of the three ponds during January, 1973.

Date	Day	Pond Sampling Site	Hydrocarbon Level (mg/l as toluene)[b]				
			Drainless Engine Pond		Drained Engine Pond		Control Pond
			BO[c]	DO[c]	BO	DO	
1/03/73	Wed.	N	nm[c]	nm	0.081	0.086	nm
1/05/73	Fri.	N	nm	0.292	nm	nm	0.000
1/11/73	Thu.	N	0.228	0.421	0.387	0.411	0.006
1/16/73	Tue.	N	0.420	1.010	nm	nm	0.010
1/16/73	Tue.	R	0.420	0.490	nm	nm	nm
1/22/73	Mon.	N	0.030	nm	0.080	nm	0.003
1/22/73	Mon.	R	0.070	nm	0.090	nm	nm

[a] Pond sampling sites: N = next to motor R = opposite side of pond from motor.

[b] Method: involves extraction of hydrocarbons into cyclohexane and subsequent determination of UV light transmittance at 212 mu.

[c] Abbreviations: BO = before motor operation; DO = during motor operation; nm = not measured.

Table 12. Dissolved oxygen and pH levels that were measured in the surface layer of the limnetic zone in each of the three ponds studied during the first and second fiscal year.

DATE	CHEMICAL PARAMETERS[a]					
	Drainless Engine Pond		Drained Engine Pond		Control Pond	
	D.O.[b] (mg/1)	pH[c]	D.O. (mg/1)	pH	D.O. (mg/1)	pH
7-28-71	7.5	4.90	8.4	5.00	7.8	5.00
8-02-71	6.7	NM	6.3	NM	7.3	NM
8-05-71	7.3	5.05	6.0	5.15	7.4	5.15
8-17-71	7.7	5.40	7.6	5.20	7.7	5.20
8-18-71	NM	5.25	NM	4.95	NM	5.05
8-25-71	5.8	5.10	6.3	5.20	NM	NM
9-07-71	NM	5.03	NM	4.95	NM	5.10
9-08-71	NM	5.03	NM	4.95	NM	5.10
9-29-71	NM	4.70	NM	4.20	NM	4.85
10-13-71	6.4	NM	7.2	NM	NM	5.75
10-29-71	7.3	5.65	8.3	5.50	NM	5.75
11-02-71	5.9	5.45	6.6	5.05	NM	5.60
12-01-71	NM	4.80	NM	4.80	NM	NM
12-27-71	NM	4.91	NM	4.78	NM	4.89
1-19-72	8.9	4.70	9.2	4.80	8.7	4.70
2-16-72	8.8	4.70	9.1	4.81	8.8	4.63
2-23-72	8.4	4.90	8.7	4.90	9.0	5.20
3-08-72	8.0	4.75	8.0	4.65	8.8	4.59
3-15-72	NM	4.63	NM	4.65	NM	4.71
3-22-72	8.2	5.20	8.8	5.70	8.7	5.40
3-29-72	7.0	5.10	6.6	5.07	7.1	5.22
4-05-72	7.5	5.25	7.2	5.20	7.3	5.25
4-12-72	7.6	5.07	7.6	5.03	7.7	5.10
4-19-72	7.0	4.85	6.4	4.97	7.2	5.15
4-26-72	6.7	5.14	7.3	5.10	7.2	5.40
5-03-72	7.1	5.37	6.7	5.35	7.0	5.01
5-10-72	7.9	5.17	6.9	5.22	7.8	5.95
5-17-72	7.4	4.98	6.6	5.15	7.4	5.06
5-24-72	7.2	4.93	7.8	4.90	7.6	5.01
5-31-72	6.8	4.95	7.2	4.95	7.5	5.05
6-07-72	6.5	5.10	6.3	5.00	7.2	5.23
6-16-72	6.3	5.08	5.8	4.98	7.0	4.89
6-23-72	7.5	5.03	7.1	5.10	7.9	5.20

Table 12, continued.

DATE	CHEMICAL PARAMETERS					
	Drainless Engine Pond		Drained Engine Pond		Control Pond	
	D.O. (mg/1)	pH	D.O. (mg/1)	pH	D.O. (mg/1)	pH
6-30-72	6.8	4.92	6.6	5.10	7.1	5.17
7-07-72	7.2	5.07	6.9	5.15	7.4	5.19
7-14-72	6.9	5.12	7.4	5.10	7.7	5.28
7-24-72	7.4	5.19	7.4	5.08	7.3	5.23
7-31-72	7.8	5.37	NM	5.25	7.7	5.17
8-07-72	7.8	5.22	7.8	5.18	7.8	5.10
8-14-72	7.6	5.06	7.5	5.11	7.6	5.01
8-21-72	7.4	5.08	7.8	5.16	7.8	5.09
8-28-72	7.6	5.00	7.9	5.02	7.9	5.07
9-04-72	7.7	4.53	7.8	4.59	7.8	4.45
9-13-72	NM	4.40	NM	4.60	NM	4.30
9-20-72	8.8	4.11	8.6	5.19	8.8	5.07
9-26-72	8.8	5.07	8.8	5.11	8.8	4.98
10-04-72	NM	5.25	NM	5.13	NM	5.47
10-11-72	NM	5.13	NM	5.07	NM	5.23
10-18-72	NM	5.03	NM	5.11	NM	5.09
10-25-72	NM	4.87	NM	5.01	NM	4.96
12-15-72	8.1	4.85	8.0	5.15	8.6	4.65
12-22-72	8.8	5.34	8.9	5.62	9.1	5.32
12-29-72	10.0	5.10	9.3	5.00	10.1	4.60
1-05-73	8.2	5.18	8.0	4.93	8.4	4.90
1-12-73	7.8	4.50	8.2	4.50	9.2	4.00
1-19-73	8.4	5.20	8.1	4.25	8.7	4.75
1-24-73	9.6	5.21	9.9	4.89	10.1	4.53
2-02-73	9.3	5.14	9.9	4.43	9.6	4.89
2-09-73	8.9	5.16	8.7	5.52	9.8	4.76
2-16-73	8.7	5.40	9.1	4.82	8.3	5.10
2-23-73	9.2	NM	9.9	NM	9.9	NM
3-02-73	9.0	4.55	8.8	4.60	9.4	4.70
3-12-73	8.6	5.12	8.5	4.85	8.4	4.92
3-16-73	8.3	4.10	7.6	4.60	8.9	4.25
3-26-73	9.2	3.65	9.6	4.70	9.7	4.30
4-02-73	8.6	NM	9.1	NM	9.4	NM
Baseline Mean	6.9	5.06	7.0	4.95	7.6	5.15
Treatment Mean	7.9	4.98	8.0	5.06	8.3	4.99

abbreviations: NM=not measured

Table 13. Comparisons of the average levels of dissolved oxygen and pH in the surface of the limnetic zone between ponds before treatment and during treatment using pooled sample t-tests and the 95 percent confidence level.

Null Hypothesis (Ho)	Parameter	Time Interval[a]	Significance	
Ho: Drainless Engine Pond = Control Pond	Dissolved Oxygen	BT, 7/28/71 to 10/13/71	.05, Reject Ho	Control > Drainless
Ho: Drainless Engine Pond = Control Pond	Dissolved Oxygen	DT,10/13/71 to 4/02/73	.05, Reject Ho	Control > Drainless
Ho: Drainless Engine Pond = Control Pond	pH	BT, 7/28/71 to 10/13/71	N.S., accept Ho	
Ho: Drainless Engine Pond = Control Pond	pH	DT,10/13/71 to 4/02/73	N.S., accept Ho	
Ho: Drained Engine Pond = Control Pond	Dissolved Oxygen	BT, 7/28/71 to 10/13/71	N.S., accept Ho	
Ho: Drained Engine Pond = Control Pond	Dissolved Oxygen	DT,10/13/71 to 4/02/73	N.S., accept Ho	
Ho: Drained Engine Pond = Control Pond	pH	BT, 7/28/71 to 10/13/71	N.S., accept Ho	
Ho: Drained Engine Pond = Control Pond	pH	DT,10/13/71 to 4/02/73	N.S., accept Ho	
Ho: Drainless Engine Pond = Drained Engine	Dissolved Oxygen	BT, 7/28/71 to 10/13/71	N.S., accept Ho	
Ho: Drainless Engine Pond = Drained Engine	Dissolved Oxygen	DT,10/13/71 to 4/02/73	N.S., accept Ho	
Ho: Drainless Engine Pond = Drained Engine	pH	BT, 7/28/71 to 10/13/71	N.S., accept Ho	
Ho: Drainless Engine Pond = Drained Engine	pH	DT,10/13/71 to 4/02/73	N.S., accept Ho	

[a] Abbreviations: BT = Before Treatment
DT = During Treatment

Since the pH of the ponds are not controlled by a carbonate buffer system, it is not possible at this time to explain the narrow pH range in terms of changes in CO_2 levels. A cursory investigation showed that the pH is primarily controlled by non-carbonates since there was less than a unit increase in pH after most of the CO_2 and HCO_3 were removed by purging a water sample with pure N_2 gas. By purging with pure CO_2 gas, the pH was driven down to 3.9. With respect to removal or release of CO_2 (photosynthesis and respiration), the ponds are strongly buffered to a maximum pH range of 2 units.

Dissolved Oxygen and Oxygen Demands

Oxygen limits were found to be close to saturation in the surface waters of the three ponds. Significantly higher dissolved oxygen levels in the limnetic zone were found in the Control Pond than in the treated ponds throughout the study (Table 13). This is most likely attributable to a higher ratio of photosynthesis to respiration in the limnetic zone of the Control Pond. Since the same relationship existed before treatment as did during treatment, the difference is considered to be normal.

No significant differences in BOD and COD levels were found between the ponds before treatment or during treatment in composite water samples collected from the limnetic zones in each pond (Table 14). BOD levels were low as they ranged less than 5 mg/1 in all three ponds from 5/01/71 to 12/09/71 (Table 15). Similarly, COD levels were low as they ranged 7 to 85 mg/1. A decline in COD was noted during the fall and is most likely attributable to the decline in the primary production of organic matter.

Micronutrients (Phosphorus and Nitrogen)

During the first annual review, a decision was made to take the necessary steps to increase the precision and accuracy of the analytical methods for measuring nutrient levels. Therefore, in April, 1972, the initial automated method was replaced with the manual ascorbic acid method (46). The resulting data is reported herein.

The phosphorus levels beginning in April 1972 reflect the increased precision and accuracy of the manual ascorbic acid techniques used during the last two-thirds of the project. Still, no significant differences in the orthophosphorus and total phosphorus levels between the ponds or within the ponds (littoral zone versus limnetic zone) were evident during the last 12 months of the study (Table 16 and 17). Orthophosphorus levels ranged from less than 0.002 to 0.043 mg/1 and total phosphorus levels ranged from less than 0.005 to 0.108 mg/1 (Table 18). Average levels of orthophosphorus and total phosphorus were found to be about 0.007 mg/1 and 0.023 mg/1, respectively. Approximately 50 percent of the orthophosphorus levels were quite low as they ranged less than 0.002 mg/1. At these lower levels, phosphorus may become limiting to algae and higher plants.

Table 14. Comparisons of the average levels of biochemical and chemical oxygen demand between ponds before treatment and during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Parameter	Time Interval	Significance
Ho: Drainless Engine Pond = Control Pond	BOD	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	BOD	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	BOD	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	BOD	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	BOD	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	BOD	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	COD	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	COD	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	COD	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	COD	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	COD	BT, 5/01/71 to 10/06/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	COD	DT, 10/20/71 to 12/15/71	N.S., accept Ho

[a] Abbreviations: BT = Before Treatment
DT = During Treatment

Table 15 . Levels of biochemical and chemical oxygen demands of composite water samples (surface and bottom water) that were collected from the limnetic zone in each of the three ponds studied during the first fiscal year.

Date	Oxygen Demands (mg/l)					
	Drainless Engine Pond		Drained Engine Pond		Control Pond	
	BOD	COD	BOD	COD	BOD	COD
5-01-71	1	24	1	24	1	20
7-28-71	3	nm	5	nm	5	nm
8-17-71	1	nm	2	nm	1	nm
8-25-71	1	18	1	36	2	26
9-03-71	nm	25	1	8	1	16
9-10-71	nm	27	1	17	1	17
9-15-71	nm	25	nm	17	1	85
9-22-71	nm	25	nm	23	nm	18
9-29-71	1	12	2	23	<1	19
10-06-71	1	12	1	17	<1	26
10-20-71	1	10	1	23	1	19
11-11-71	1	7	1	17	1	10
11-17-71	2	19	2	19	1	17
12-02-71	2	12	1	16	1	19
12-09-71	2	16	2	13	1	9
Baseline Mean	1	21	2	21	2	28
Treatment Mean	2	13	1	21	1	14

Abbreviations: nm = not measured.

Table 16. Comparisons of average orthophosphorus and total phosphorus levels between ponds during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Parameter	Sampling Site[a]	Significance
Ho: Drainless Engine Pond = Control Pond	Orthophosphorus	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Orthophosphorus	LZ	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Orthophosphorus	GB	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Orthophosphorus	LZ	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Orthophosphorus	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Orthophosphorus	LZ	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total Phosphorus	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total phosphorus	LZ	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Phosphorus	GB	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total Phosphorus	LZ	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Phosphorus	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Total Phosphorus	LZ	N.S., accept Ho

[a] Abbreviations: GB = Grass Bed Zone
LZ = Limnetic Zone

Table 17. Comparisons of average orthophosphorus and total phosphorus levels within ponds during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Parameter	Pond	Significance
Ho: Grass Bed Zone = Limnetic Zone	Orthophosphorus	Drainless Engine Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Orthophosphorus	Drained Engine Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Orthophosphorus	Control Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Total Phosphorus	Drainless Engine Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Total Phosphorus	Drained Engine Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Total Phosphorus	Control Pond	N.S., accept Ho

Table 18. Orthophosphorus and total phosphorus levels of composite water samples that were collected from the grassbed zone and the limnetic zone in each of the three ponds studied during the time period of April 4, 1972 to March 28, 1973.

		Orthophosphorus (mg/l)			Total Phosphorus (mg/l)		
Date	Pond Sampling Site	Drainless Engine Pond	Drained Engine Pond	Control Pond	Drainless Engine Pond	Drained Engine Pond	Control Pond
4-04-72	GB	0.004	0.004	0.014	0.016	0.006	0.016
4-04-72	LZ	0.008	0.006	0.006	0.008	0.014	0.016
4-26-72	GB	NM	NM	NM	NM	0.014	0.010
4-26-72	LZ	NM	NR	0.014	0.014	0.012	0.014
6-06-72	GB	0.020	0.028	0.010	0.028	0.026	0.020
6-06-72	LZ	0.100	0.042	0.012	0.108	0.082	0.024
7-07-72	GB	<0.002	<0.002	<0.002	0.008	0.008	0.018
7-07-72	LZ	<0.002	<0.002	<0.002	0.008	0.014	0.012
7-27-72	GB	<0.002	<0.002	<0.002	0.004	0.064	0.030
7-27-72	LZ	<0.002	<0.002	<0.002	0.070	0.038	0.016
8-30-72	GB	0.004	0.004	0.004	0.020	0.016	0.020
8-30-72	LZ	0.004	0.008	0.004	0.030	0.020	0.020
9-27-72	GB	<0.002	<0.002	<0.002	0.016	0.024	0.040
9-27-72	LZ	<0.002	<0.002	<0.002	0.004	0.010	0.024
10-30-72	GB	0.008	0.006	0.012	0.014	0.026	0.010
10-30-72	LZ	0.012	0.008	0.012	0.020	0.036	0.024
12-04-72	GB	0.002	0.022	0.014	0.018	0.016	0.028
12-04-72	LZ	0.022	0.024	0.012	0.026	0.026	0.022
12-21-72	GB	<0.002	<0.002	<0.002	0.022	0.022	0.022
12-21-72	LZ	<0.002	<0.002	<0.002	0.024	0.018	0.036
1-05-73	GB	0.016	<0.002	0.011	0.016	0.018	0.020
1-05-73	LZ	0.008	<0.002	<0.002	0.020	0.018	0.024
2-15-73	GB	<0.002	<0.002	<0.002	0.032	0.024	0.080
2-15-73	LZ	<0.002	<0.002	<0.002	0.060	0.020	0.052
3-28-73	GB	<0.002	0.002	0.002	0.064	0.025	0.281
3-28-73	LZ	0.008	0.006	<0.002	0.097	0.094	0.066
Mean		0.009	0.007	0.005	0.030	0.027	0.027

abbreviations: GB =grass bed; DW=deep water; NM = not measured

No significant differences in the levels of nitrate, including nitrite, were evident between ponds or within ponds (Table 19 and 20). In all three ponds, nitrate levels followed several trends that can be explained by natural events (Table 21). During the peak of the growing season in July, the nitrate levels in all three ponds declined to minimal levels of less than 0.004 mg/l (as N) as productivity rates in the grassbed community peaked. Following the growing season the nitrate levels in all three ponds increased to maximal levels of 0.1 to 0.4 mg/l (as N) as the decomposition of the macrophytes began producing nitrate and other nitrogenous compounds. During the following spring, nitrates again began declining to minimal levels. This trend was occasionally interrupted by peaks of high nitrate levels in the Control Pond and Drainless Engine Pond.

During 1972 and 1973, ammonia levels ranged from 0.01 to 0.17 mg/l as N (Table 22). As the data show, no systematic seasonal variation was noted nor were significant differences seen between the ponds (Table 19 and 20). The average ammonia level during this period was found to be 0.06 mg/l. Statistical comparisons of the ammonia levels within ponds disclosed that the Drained Engine Pond exhibited a higher level in its limnetic zone than in its grassbed zone. This is likely a reflection of the high grassbed production observed in the Drained Engine Pond.

In the Drained and Drainless Engine Ponds, no significant differences in organic nitrogen were observed within the ponds nor between the Control and the two test ponds with the exception of one case (Table 23 and 24). The organic nitrogen levels in the surface of the limnetic zone in the Drainless Engine Pond were less than those in the Drained Engine Pond before treatment. These lower levels in the surface waters of the Drainless Engine Pond were possibly due to less mixing by wind and wave action associated with the greater protection against wind in comparison to the other ponds.

The annual trend of organic nitrogen in the three ponds was similar and possibly related to the balance between growth and decomposition of the grassbeds (Table 25). Generally lower levels of organic nitrogen occurred at the beginning of the growing season (Table 25). However, the increased plant production during the growing season replenished the organic nitrogen reservoir. During the dormant season, the reservoir of organic compounds that had accumulated over the past growing season was most likely used as a source of energy by the heterotrophs. By early spring, the organic nitrogen reservoir had been depleted to low levels.

Table 19. Comparisons of average nitrate and ammonia levels between ponds during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Parameter	Sampling Site[a]	Significance
Ho: Drainless Engine Pond = Control Pond	Nitrate	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Nitrate	LZ	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Nitrate	GB	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Nitrate	LZ	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Nitrate	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Nitrate	LZ	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Ammonia	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Ammonia	LZ	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Ammonia	GB	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Ammonia	LZ	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Ammonia	GB	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Ammonia	LZ	N.S., accept Ho

Table 20. Comparisons of average nitrate and ammonia levels within ponds during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Parameter	Pond	Significance
Ho: Grass Bed Zone = Limnetic Zone	Nitrate	Drainless Engine Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Nitrate	Drained Engine Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Nitrate	Control Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Ammonia	Drainless Engine Pond	N.S., accept Ho
Ho: Grass Bed Zone = Limnetic Zone	Ammonia	Drained Engine Pond	.05, reject Ho, LZ >GB
Ho: Grass Bed Zone = Limnetic Zone	Ammonia	Control Pond	N.S., accept Ho

[a] Abbreviations: GB = Grass Bed Zone
LZ = Limnetic Zone

Table 21. Levels of nitrate-nitrogen including nitrite-nitrogen for composite water samples that were collected from the grass-bed zone and the limnetic zone in each of the three ponds during the time period of April 26, 1972 to March 28, 1973.

Date	Pond[a] Sampling Site	Levels of Nitrate plus Nitrite-Nitrogen (mg/l)		
		Drainless Engine Pond	Drained Engine Pond	Control Pond
4-26-72	GB	0.044	0.036	0.022
4-26-72	LZ	0.024	0.016	0.020
7-07-72	GB	0.004	0.004	0.004
7-07-72	LZ	0.004	0.004	0.004
7-27-72	GB	0.038	0.018	0.042
7-27-72	LZ	0.012	0.012	0.012
8-30-72	GB	0.050	0.050	0.064
8-30-72	LZ	0.056	0.050	0.064
9-27-72	GB	0.370	0.050	0.070
9-27-72	LZ	0.260	0.140	0.150
10-30-72	GB	0.036	0.024	0.080
10-30-72	LZ	0.036	0.020	0.084
12-04-72	GB	0.030	0.020	0.244
12-04-72	LZ	0.020	0.010	0.190
12-21-72	GB	0.016	0.016	0.106
12-21-72	LZ	0.016	0.010	0.100
1-05-73	GB	0.090	0.100	0.250
1-05-73	LZ	0.100	0.090	0.274
2-15-73	GB	0.400	0.002	0.002
2-15-73	LZ	0.002	0.002	0.002
3-28-73	GB	0.030	0.028	0.034
3-28-73	LZ	0.032	0.034	0.054
Mean		0.076	0.033	0.085

[a] abbreviations: GB=grassbed zone; LZ = limnetic zone

Table 22. Ammonia-nitrogen levels of composite water samples (surface and bottom water) that were collected from the grassbed zone and the limnetic zone of each of the three ponds during the second fiscal year.

Date	Pond Sampling Site	Ammonia-Nitrogen Level (mg/l)		
		Drainless Engine Pond	Drained Engine Pond	Control Pond
7-27-72	GB	0.05	0.04	0.04
7-27-72	LZ	0.10	0.10	0.03
8-30-72	GB	0.03	0.06	0.06
8-30-72	LZ	0.07	0.08	0.05
9-27-72	GB	0.08	0.07	0.02
9-27-72	LZ	0.03	0.08	0.09
10-30-72	GB	0.04	0.03	0.09
10-30-72	LZ	0.05	0.07	0.09
12-04-72	GB	0.01	0.07	0.14
12-04-72	LZ	0.02	0.07	0.13
12-21-72	GB	0.06	0.05	0.09
12-21-72	LZ	0.10	0.05	0.10
1-05-73	GB	0.06	0.04	0.07
1-05-73	LZ	0.05	0.05	0.07
2-15-73	GB	0.03	0.05	0.03
2-15-73	LZ	0.05	0.06	0.04
3-28-73	GB	0.04	0.03	0.05
3-28-73	LZ	0.03	0.04	0.02
Mean		0.05	0.06	0.07

abbreviations: GB=grassbed zone; LZ = limnetic zone

Table 23. Comparisons of the average levels of organic nitrogen between ponds before treatment and during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)	Sampling Site	Time Interval [a]	Significance
Ho: Drainless Engine Pond = Control Pond	Surface of Limnetic Zone	BT, 7/28/71 to 9/22/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Surface of Limnetic Zone	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Bottom of Limnetic Zone	BT, 7/28/71 to 9/22/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Bottom of Limnetic Zone	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Composite of Grass Bed Zone	DT, 4/04/72 to 3/28/73	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Composite of Linmetic Zone	DT, 1/04/72 to 3/28/73	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Surface of Limnetic Zone	BT, 7/28/71 to 9/22/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Surface of Limnetic Zone	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Bottom of Limnetic Zone	BT, 7/28/71 to 9/22/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Bottom of Limnetic Zone	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Composite of Grass Bed Zone	DT, 4/04/72 to 3/28/73	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Composite of Limnetic Zone	DT, 1/04/72 to 3/28/73	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Surface of Limnetic Zone	BT, 7/28/71 to 9/22/71	.05, reject Ho; Drained > Drainless
Ho: Drainless Engine Pond = Drained Engine Pond	Surface of Limnetic Zone	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Bottom of Limnetic Zone	BT, 7/28/71 to 9/22/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Bottom of Limnetic Zone	DT, 10/20/71 to 12/15/71	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Composite of Grass Bed Zone	DT, 4/04/72 to 3/28/73	N.S., accept Ho
Ho: Drainless Engine Pond = Drained Engine Pond	Composite of Limnetic Zone	DT, 1/04/72 to 3/28/73	N.S., accept Ho

Table 24. Comparisons of the average levels of organic nitrogen within ponds before treatment and during treatment using pooled sample t-tests and the 95% confidence interval.

Null Hypothesis (Ho)[b]	Pond	Sampling Interval[a]	Significance
Ho: Surface of LZ = Bottom of LZ	Drainless Engine Pond	BT, 7/28/71 to 9/22/71	.05, reject Ho; Bottom > surface
Ho; Surface of LZ = Bottom of LZ	Drained Engine Pond	BT, 7/28/71 to 9/22/71	N.S., accept Ho
Ho: Surface of LZ = Bottom of LZ	Control Pond	BT, 7/28/71 to 9/22/71	N.S., accept Ho
Ho: Surface of LZ = Bottom of LZ	Drainless Engine Pond	DT, 10/20/71 to 3/10/72	N.S., accept Ho
Ho: Surface of LZ = Bottom of LZ	Drained Engine Pond	DT, 10/20/71 to 3/10/72	N.S., accept Ho
Ho: Surface of LZ = Bottom of LZ	Control Pond	DT, 10/20/71 to 3/10/72	N.S., accept Ho
Ho: Composite of LZ = Composite of GB	Drainless Engine Pond	DT, 4/04/72 to 3/28/73	N.S., accept Ho
Ho: Composite of LZ = Composite of GB	Drained Engine Pond	DT, 4/04/72 to 3/28/73	N.S., accept Ho
Ho: Composite of LZ = Composite of GB	Control Pond	DT, 4/04/72 to 3/28/73	N.S., accept Ho

[a] Abbreviations: BT = Before Treatment; DT = During Treatment

[b] Abbreviations: LZ = Limnetic Zone; GB = Grass Bed Zone

Table 25 . Organic nitrogen levels of water samples that were collected from the surface and bottom waters in the limnetic zone in each of the three ponds studied during the first fiscal year and organic nitrogen levels of composite water samples (surface and bottom water) that were collected from the grassbed zone and the limnetic zone for each of the three ponds during the second fiscal year.

Date	Pond Sampling Site	Organic Nitrogen Level (mg/l)[a,b]		
		Drainless Engine Pond	Drained Engine Pond	Control Pond
7-28-71	S	0.40	1.23	0.96
7-28-71	B	0.17	0.50	0.67
8-25-71	S	0.50	0.76	0.17
8-25-71	B	0.17	0.67	0.67
9-03-71	S	0.66	1.06	1.06
9-03-71	B	0.66	1.06	1.59
9-10-71	S	0.13	0.59	0.39
9-10-71	B	0.86	0.33	0.53
9-15-71	S	0.33	0.66	1.06
9-15-71	B	0.59	1.39	0.53
9-22-71	S	0.48	1.02	1.57
9-22-71	B	0.68	0.54	0.54
10-20-71	S	0.94	0.66	0.43
10-20-71	B	0.32	0.75	0.55
11-11-71	S	0.21	0.27	0.18
11-11-71	B	0.11	0.25	0.34
12-02-71	S	0.13	0.04	NM
12-02-71	B	0.69	0.04	0.08
12-15-71	S	NM	1.05	0.96
12-15-71	B	NM	1.74	1.32
1-04-72	LZ	0.98	1.93	0.66
1-27-72	LZ	0.40	0.62	0.67
2-10-72	LZ	0.39	0.34	0.43
2-23-72	LZ	0.75	0.87	0.76
3-10-72	LZ	0.72	0.80	1.02
4-04-72	GB	0.25	0.27	0.38
4-04-72	LZ	0.16	0.31	0.48
4-26-72	GB	0.47	0.77	0.24
4-26-72	LZ	0.16	0.38	0.33

Table 25 Continued

Date	Pond Sampling Site	Organic Nitrogen Level (mg/l) Drainless Engine Pond	Drained Engine Pond	Control Pond
6-06-72	GB	1.02	0.40	0.45
6-06-72	LZ	0.34	0.91	1.08
7-07-72	GB	0.46	0.82	0.79
7-07-72	LZ	0.87	0.69	1.01
7-27-72	GB	0.61	0.47	0.48
7-27-72	LZ	0.37	0.66	0.30
8-30-72	GB	0.40	0.70	0.90
8-30-72	LZ	0.50	0.70	0.50
9-27-72	GB	0.50	0.59	0.65
9-27-72	LZ	0.52	0.67	0.92
10-30-72	GB	0.67	0.90	0.73
10-30-72	LZ	0.59	1.17	1.13
12-04-72	GB	0.55	1.30	0.85
12-04-72	LZ	1.00	0.95	0.70
12-21-72	GB	0.45	0.45	NM
12-21-72	LZ	0.51	0.61	0.50
1-05-73	GB	0.44	0.56	0.52
1-05-73	LZ	0.33	0.50	0.43
2-15-73	GB	0.40	0.70	0.50
2-15-73	LZ	1.00	0.80	0.50
3-28-73	GB	0.34	0.55	0.45
3-28-73	LZ	0.30	0.61	0.29
Baseline Mean		0.47	0.82	0.81
Treatment Mean		0.51	0.69	0.61

Not measured (NM)

SUMMARY

1. Before treatment, no significant differences were observed among the ponds for the levels of the following constituents:

   Iron
   Magnesium
   Chloride
   Sulfate
   Fluoride
   Total Solids
   Suspended Solids
   Dissolved Solids
   Total Hardness
   Conductivity
   Turbidity
   pH
   BOD
   COD

   Two significant differences, however, were found among the three ponds during the baseline investigation. The dissolved oxygen level in the Control Pond was found to be significantly greater than that in the Drainless Engine Pond and the organic nitrogen level in the Drained Engine Pond was found to be significantly greater than that in the Drainless Engine Pond.

2. Of the twenty-five chemical parameters investigated during the treatment, no effects were observed in the following areas:

   Dissolved Solids
   Suspended Solids
   Total Solids
   Hardness
   Conductivity
   Turbidity
   Hydrogen Ion Potential
   Dissolved Oxygen
   Chloride
   Fluoride
   Sulfate
   Magnesium
   Iron

   Variation in the natural background chemical oxygen demand (7 to 85 mg/l) precluded isolating the relatively small contributions made by the outboard marine engines at least by those test procedures. Similarly, there were seasonal variations in total phosphorus, orthophosphorus, ammonia, nitrite, nitrate and organic nitrogen but no relationship with outboard engine operation could be found.

3. During treatment, two differences in the chemical parameters were observed among the three ponds which may be attributed to outboard motor emissions.

   (a) The level of dissolved organic carbon in the limnetic zone was found to be significantly greater in the Drained Engine Pond than in the other ponds possible due to a direct result of engine emissions. The Drained Engine Pond received a greater amount of unburned organic emissions than did the Drainless Engine Pond. Further investigation showed that engine operation in the test ponds increased the level of aromatic hydrocarbons and it is expected that the level of other organic emissions were also increased.

   (b) The level of total inorganic carbon in the limnetic zone was found to be significantly greater in the Drained and Drainless

Engine Ponds than in the Control Pond. The higher inorganic carbon levels may be partly attributed to the carbon dioxide emissions from the outboard motors.

4. The primary form of inorganic carbon is carbon dioxide, which exists at levels less than the rate of carbon dioxide assimilation in the grassbed zone during the growing seasons. Consequently, it is highly possible that the availability of carbon dioxide limits grassbed production during the spring, summer and early fall.

5. Carbon dioxide enrichment through engine emissions and mass transport of carbon dioxide by induced water circulation may increase the availability of carbon dioxide to the grassbed community and thereby increase the productivity of the grassbed community. In the less productive limnetic zone, however, an increase in primary productivity is not expected to result from an increase in the availability of carbon dioxide.

SECTION VI

MACROPHYTES AND ATTACHED ALGAE

INTRODUCTION

The larger vascular aquatic plant species may be the most important biological component of the treatment lakes. These macrophytes are readily visible, easily measurable, and most importantly, they function as the basis of the lacustrine food web. Macrophytes provide shelter for many aquatic invertebrates, juvenile fish, and the immature stages of many terrestrial invertebrates. They also provide a substrate for periphyton (microscopic attached algae), and as they die they furnish sustenance for the detritivorous food chain.

The macrophytes occur in four horizontal zones, namely, the epilittoral, the eulittoral, the sublittoral, and the limnetic zones. The epilittoral zone, located above the high water line, supports terrestrial plants that are capable of existing in a moist soil. This zone supports numerous species of low broad-leafed plants (forbs) and sedges. The eulittoral zone serves as an ecotone between the epilittoral and the sublittoral zones and supports plant species common to both zones. As much as a 1-2 meter fluctuation of the water level inundates or exposes the eulittoral zone.

The third zone, the sublittoral zone is inundated at all times. This zone supports only a few macrophyte species since only a small amount of sunlight penetrates to the bottom.

The limnetic zone is the fourth and deepest zone. Since there is little sunlight penetration at these depths, there is virtually no submersed vegetation. However, rooted plants such as water lillies are often found with their leaf petioles extending up and, in part, supporting their emergent leaves on or above the water's surface. Initially these species colonize in shallow water. Once established, they store large amounts of high-energy organic matter in massive subterranean stolons. This provides the necessary energy for growth immediately following the dormant season. This growth mechanism is triggered by an increased water temperature during the spring. Stem growth occurs and extends the leaves to the surface, thus allowing the plant to photosynthesize and replenish its subterranean food resources.

A cross-section of the treatment ponds, illustrating the vegetation zones and their associated macrophytes is depicted in Figure 1.

The periphyton as previously mentioned are the microscopic attached plants that are found growing on the submerged surfaces of the macrophytes in the treatment lakes. They are commonly observed as the slimy green, yellow or brown coating on submerged plants. Like plankton, the periphyton is comprised of numerous species of algae exhibiting wide ranges in abundance, standing crop, and metabolic activity. They are important to the food web in that they provide

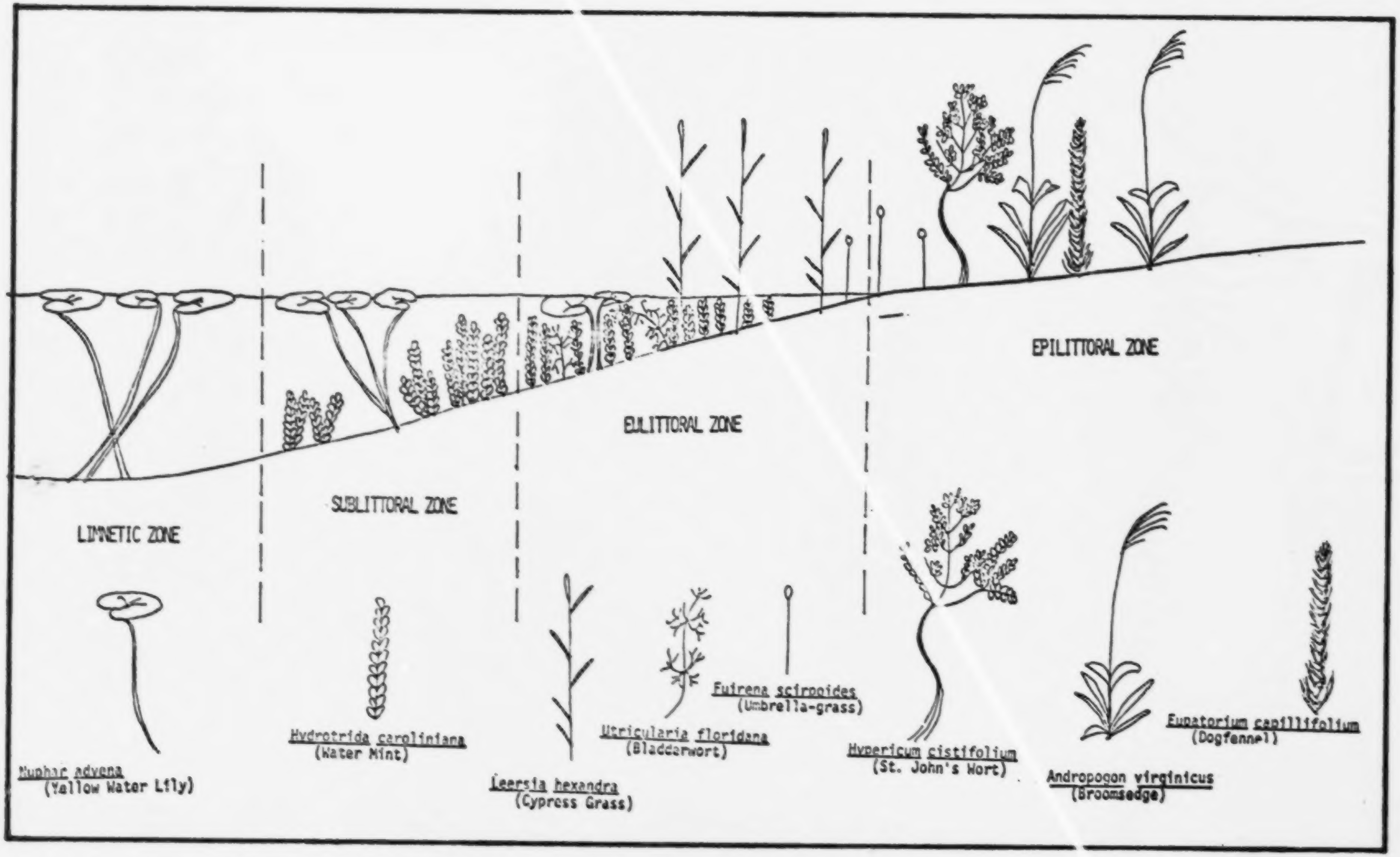
LIMNETIC ZONE
SUBLITTORAL ZONE
EULITTORAL ZONE
EPILITTORAL ZONE
Nuphar advena
(Yellow Water Lily)
Hydrotrida caroliniana
(Water Mint)
Leersia hexandra
(Cypress Grass)
Utricularia floridana
(Bladderwort)
Fuirena scirpoides
(Umbrella-grass)
Hypericum cistifolium
(St. John's Wort)
Andropogon virginicus
(Broomsedge)
Eupatorium capillifolium
(Dogfennel)

Figure 1. A cross-section of the vegetation of the three test ponds, illustrating the differing macrophyte associations among the epilittoral, eulittoral, sublittoral, and limnetic zones.

a major food source to the numerous small fish and invertebrate species. Furthermore, they continue to produce organic matter during the winter after the macrophytes have gone into dormancy.

FIELD PROCEDURES

Macrophyte biomass and species composition were determined for the eulittoral and sublittoral zones in each pond on a seasonal basis. All vegetation (including roots) within randomly selected plots of $0.25\ m^2$ were collected in duplicate from each of the aforementioned zones and measured volumetrically. Species compositions were determined along transects made through the eulittoral and sublittoral zones adjacent to the test plots. Plants were collected at 10 cm intervals along the transect, and then counted and identified.

Periphyton biomass and growth rates were measured at bimonthly intervals in the sublittoral zone using glass slide substrates (39). Artificial substrates were submersed in each pond to a depth of 5-15 cm. New slides were used at the start of each bimonthly test and removed in 2-4 weeks to reduce overgrowth and subsequent sloughing.

Primary productivity in the grassbed community of each pond was measured in clear plastic domes (0.3 m diameter, 0.5 m high) at monthly intervals. Domes were placed over paired sections of the plant bed (sublittoral zone) and dissolved oxygen levels were measured over a diel cycle with a YSI oxygen probe that was simultaneously calibrated by a Winkler titration. Estimates of gross primary productivity were calculated by the addition of oxygen increase during the photoperiod and oxygen decline during the dark period. Grassbed productivity is considered to be primarily the autotrophic activity of the macrophytes and periphyton with small contributions from the benthic algae and the phytoplankton except during the winter when macrophytes were dormant.

RESULTS

Species Composition and Distribution

The same variety of plant species were found in the epilittoral zone around all three test ponds (Table 26). Broomsedge (*Andropogon virginicus*), a grass, was by far the most common. Dogfennel (*Eupatorium capillifolium*), yellow nutsedge (*Cyperus esculentus*) yellow-eye grass (*Xyris caroliniana*), and St. Johns wort (*Hypericum cistifolium*) were also common. Except within the fences surrounding the Drained Engine and Drainless Engine Ponds, the standing crop of these and other species were minimized by grazing cattle.

Table 26. Species, habitat preference, and relative abundances of the common aquatic plants.

SPECIES	Abundance[a] Epilittoral	Shallow Eulittoral	Depp Eulittoral	Sublittoral	Limnetic
Andropogon virginicus (Broomsedge)	D				
Drosera capillaris (Sundew)	C				
Centella asiatica (Coinwort)	C				
Cyperus esculentus (Yellow Nutsedge)	C	UC			
Xyris caroliniana (Yelloweye Grass)	C	UC			
Hypericum cistifolium (St. John's Wort)	C	UC			
Eupatorium capillifolium (Dogfennel)	C	UC			
Eriocaulon decangulare (Pipewort)	C	UC			
Hydrocotyle umbellata (Pennywort)	C	C			
Fuirena scirpoides (Umbrella-grass)		C	C		
Leersia hexandra (Cypress Grass)		C	C		
Nuphar advena (Yellow Water Lily)		UC	C	C	UC
Ludwigia palustris (Water Purslane)		UC			
Hydrotrida caroliniana (Water Mint)		C	C/LD	C	
Mayaca fluviatilis (Bog-moss)		C			
Utricularia floridana (Bladderwort)		UC	C/LD	C	
Utricularia foliosa (Greater Bladderwort)				LC	
Juncus repens (Carpet Rush)		LD			
Oedogonium/*Spirogyra*/ *Mougeotia* Algal Mat		LC			

[a]Abbreviations: D = Dominant
LD = Locally Dominant
C = Common
LC = Locally Common
UC = Uncommon
C/LD = Common in most situations, but locally dominant in others.

Although the population densities for each plant species of the eulittoral zone varied from pond to pond, the species found in each were essentially the same (Table 26). Common emergent species in the shallow areas of the eulittoral zone were pennywort (Hydrocotyle umbellata), umbrella grass (Fuirena scirpoides), and cypress grass (Leersia hexandra). Common submersed species were water mint (Hydrotrida caroliniana), bladderwort (Utricularia spp.), and to a lesser extent, bog-moss (Mayaca fluviatilis). An algal mat, containing mostly Oedogonium, Spirogyra, and Mougeotia, occurred on occassion.

The deep-eulittoral zone, having less available light, supported fewer submersed species than the shallow-eulittoral zone. This is evident in Table 26 as only water mint and bladderwort were observed in each pond. Emergents which are subjected to high light intensity included cypress grass, umbrella grass, and the yellow water lily (Nuphar advena).

The sublittoral zones of the three test ponds were observed to support water mint, two species of bladderwort (Utricularia floridana and U. foliosa), and the yellow water lily. This zone exhibited the deepest water of the three zones studied, and consequently had the lowest light levels at the bottom depths.

Macrophyte Biomass

The biomass of the shallow-eulittoral zone was similar in all three ponds as shown in Figure 2. During the entire field study the average biomass was 0.82, 0.80, and 1.12 liter/m^2 in the shallow-eulittoral zone of the Control, Drainless Engine, and Drained Engine Ponds, respectively (Table 27). Using a pooled sample t-test no significant difference was observed among the shallow-eulittoral zones of the three ponds at the 95 percent level of confidence (Table 28).

Obvious differences were noted in the biomass of the deep-eulittoral zones (Figure 3,4, and 5) of the three test ponds. The biomass of both zones in the Drained Engine Pond was greater than that exhibited by either of the other two ponds. The biomass of the deep-eulittoral and sublittoral zones of the Drained Engine Pond was 1.69 and 1.53 liter/m^2, respectively. This compares to only 0.74 and 0.37 liter/m^2, and 0.77 and 0.58 liter/m^2, for the Drainless Engine Pond and the Control Pond, respectively.

At the termination of the field investigation, bladderwort occupied virtually the entire water mass of the Drainless Engine Pond, wheras carpet rush occupied only the benthic part of the water column in the shallow-eulittoral zone of the Control Pond. Although the data show no statistical difference in biomass between the Control Pond and the Drainless Engine Pond (Table 28), this is an artifact, since it was quite evident through visual observations that there were differences in biomass between the foliage of the two ponds at the end of the field study. Only a small portion of the bladderwort's biomass is underground, whereas perhaps as much as 50 percent of the biomass of carpet rush is underground in the form of roots and stems.

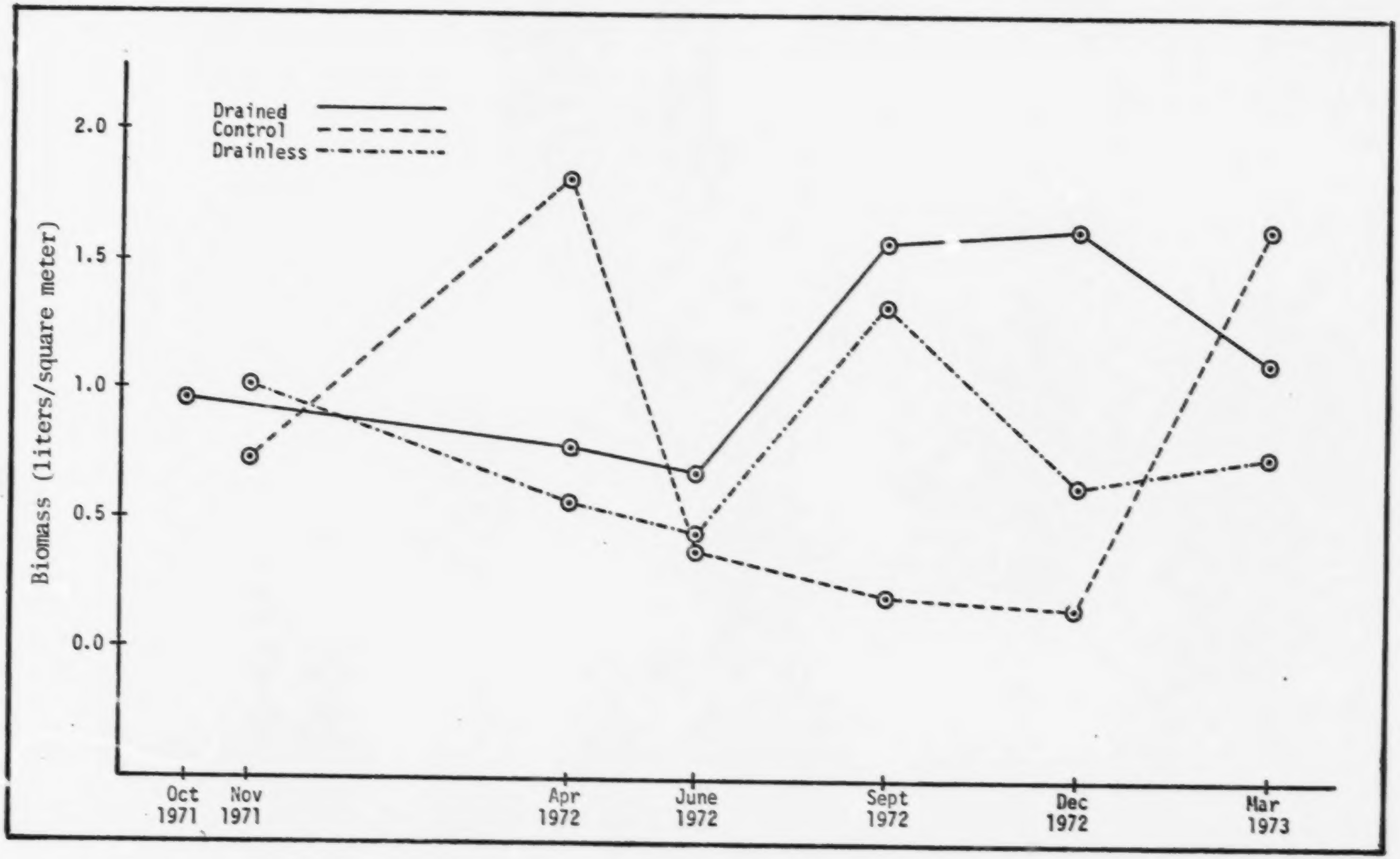

Figure 2. Macrophyte biomass (in liters per square meter) of the shallow-eulittoral zone of the three test ponds.

Table 27. Macrophyte biomass of the shallow-eulittoral, deep-eulittoral, and sublittoral zones of the three test ponds.

	Macrophyte Biomass (liters/m^2)								
Test Pond	Oct. 1971	Nov. 1971	Apr. 1972	June 1972	Sept. 1972	Dec. 1972	Mar. 1973	Mean	Standard Deviation
Control									
Shallow-Eulittoral		0.72	1.80	0.38	0.20	0.18	1.64	0.82	0.72
Deep-Eulittoral		0.86	1.75	0.38	0.24	0.36	0.90	0.75	0.56
Sublittoral		1.35	0.12	0.10	0.38	0.16	0.09	0.37	0.49
Total		2.93	3.67	0.86	0.82	0.70	2.63	1.94	1.30
Drainless Engine									
Shallow-Eulittoral		1.01	0.57	0.45	1.34	0.64	0.76	0.80	0.33
Deep-Eulittoral		1.22	0.94	0.23	0.70	0.70	0.85	0.77	0.33
Sublittoral		0.87	1.16	0.37	0.34	0.30	0.47	0.58	0.35
Total		3.10	2.67	1.05	2.38	1.64	2.08	2.15	0.73
Drained Engine									
Shallow-Eulittoral	0.96		0.77	0.68	1.58	1.63	1.12	1.12	0.40
Deep-Eulittoral	0.79		1.60	0.79	2.91	1.27	2.79	1.69	0.95
Sublittoral	1.50		0.48	0.49	1.99	1.41	3.33	1.53	1.06
Total	3.25		2.85	1.96	6.48	4.31	7.44	4.38	2.16

	Mean	Std Dev
Shallow-Eulittoral	0.91	0.18
Deep-Eulittoral	1.07	0.54
Sublittoral	0.83	0.62
Total	2.82	1.35

Table 28. Comparisons of average macrophyte biomass between ponds during treatment using pooled sample t-tests and the 95 percent level of confidence.

	ANOVA			
NULL HYPOTHESIS: Pond$_1$ Biomass = Pond$_2$ Biomass	ZONE[a]	CALCULATED[b] F-VALUE	TREATMENT OF NULL HYPOTHESIS	CORRELATION COEFFICIENT
Control, Drainless	S-Eu	<0.01	Accept	-0.30
	D-Eu	<0.01	Accept	0.53
	S	0.78	Accept	0.33
	Total	0.13	Accept	0.70
Control, Drained	S-Eu	0.80	Accept	-0.51
	D-Eu	4.39	Accept	-0.06
	S	5.94	Reject	0.02
	Total	5.73	Reject	-0.01
Drained, Drainless	S-Eu	2.39	Accept	0.67
	D-Eu	5.01	Reject	0.56
	S	4.30	Accept	-0.39
	Total	5.84	Reject	0.41

[a] Tabulated F-value = 4.96

[b] S-Eu = Shallow - Eulittoral
D-Eu = Deep - Eulittoral
S = Sublittoral

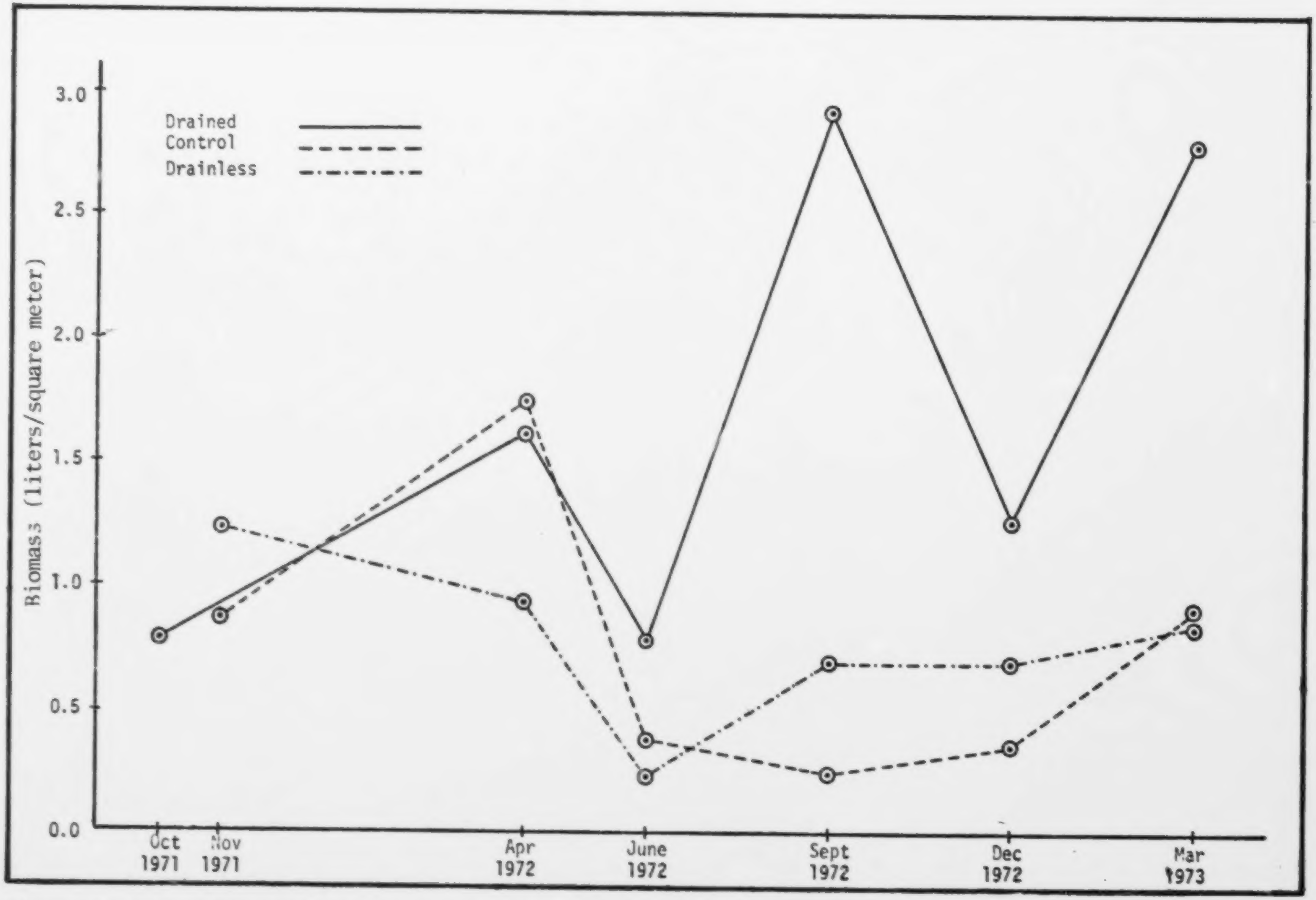

Figure 3. Macrophyte biomass (in liters per square meter) of the deep-eulittoral zone of the three test ponds.

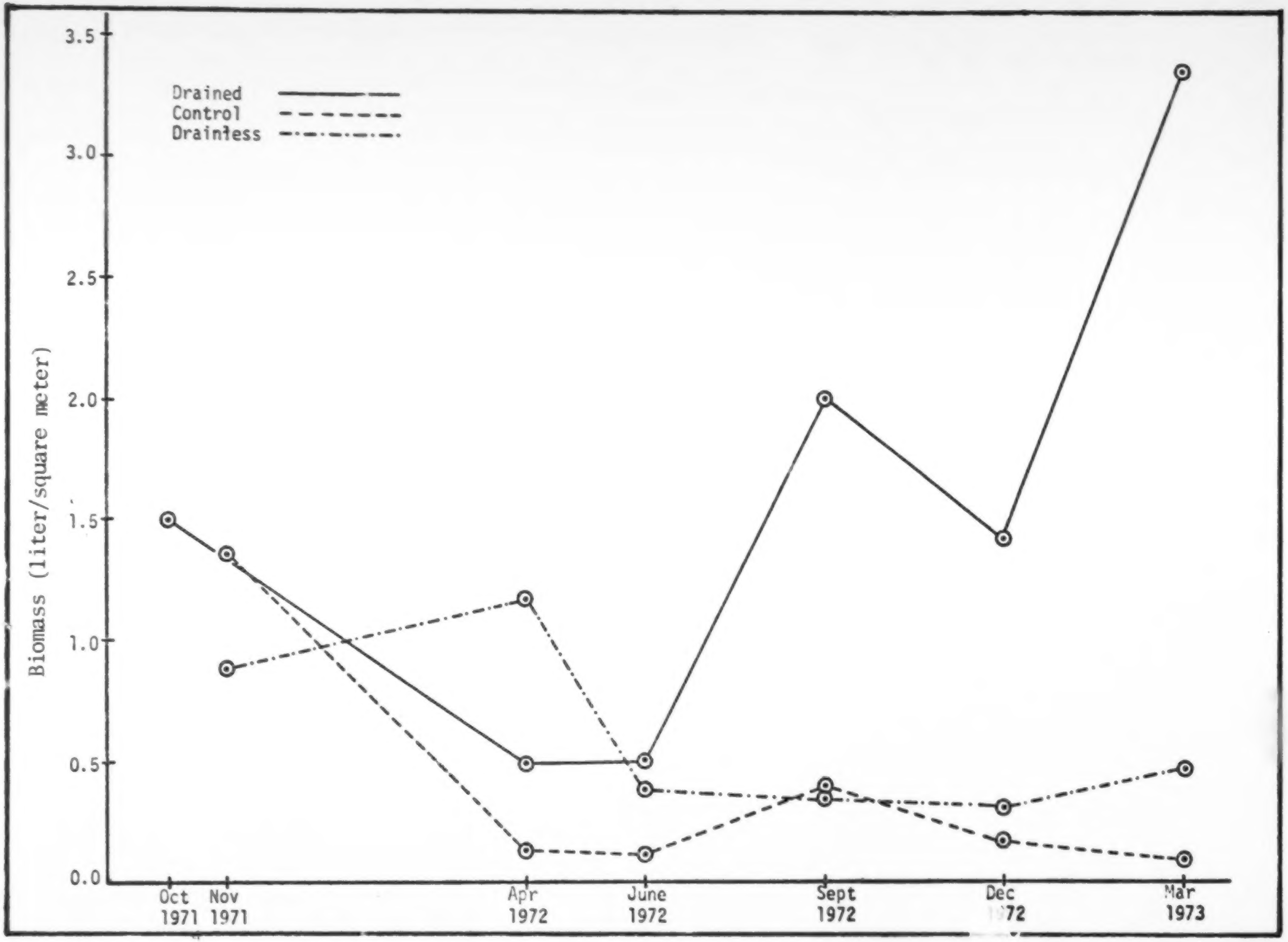

Figure 4. Macophyte biomass (in liters per square meter) of the sublittoral zone of the three test ponds.

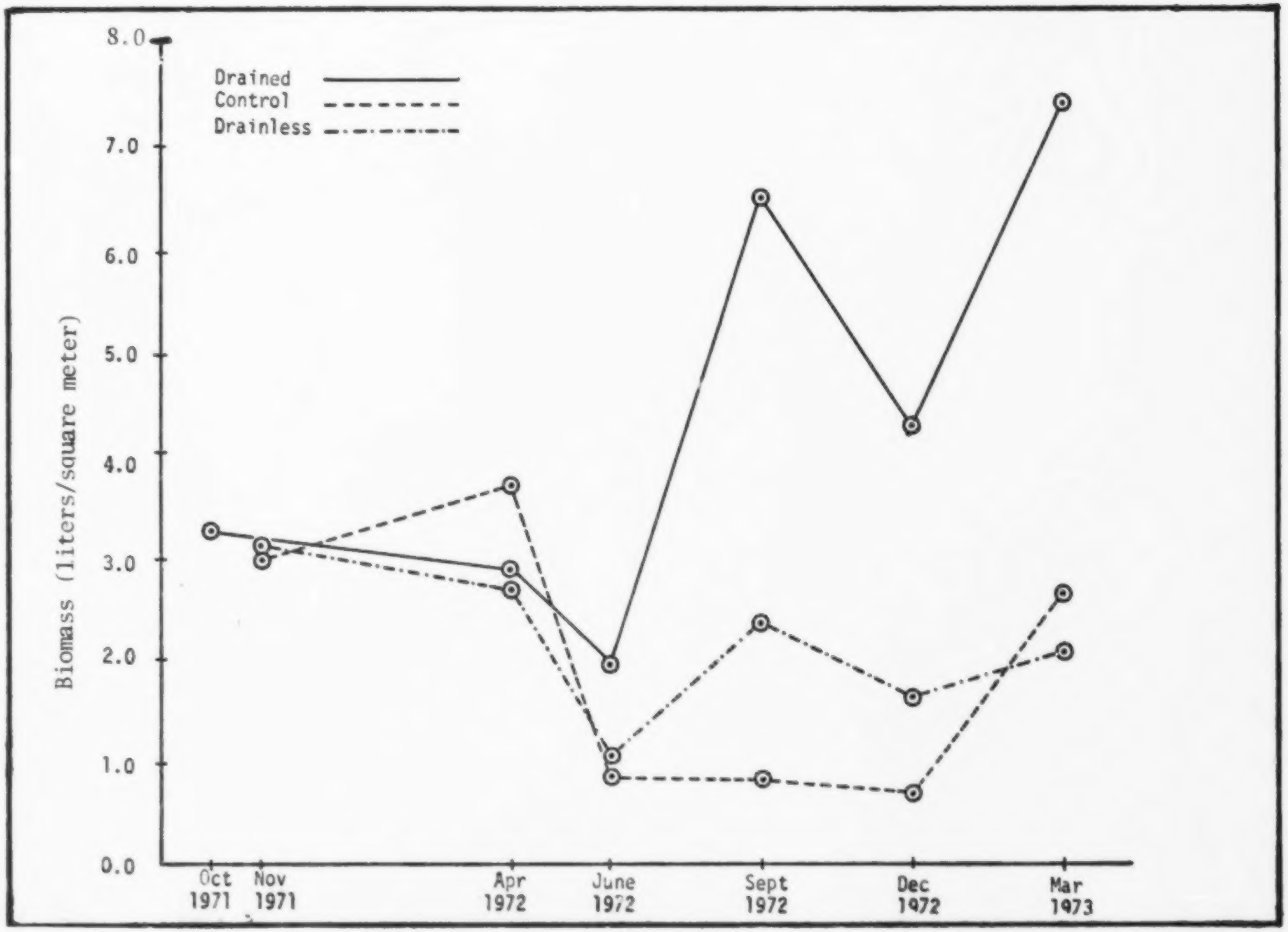

Figure 5. Total macrophyte biomass (in liters per square meter) of the shallow-eulittoral, deep-eulittoral, and sublittoral zone of the three test ponds.

Succession of Macrophytes

The Control Pond supported a dense and widespread growth of bladderwort at the beginning of the study. In spite of the mild 1971-72 winter, the density of bladderwort decreased substantially and emerged in only moderate quantities during the 1972 growing season (Table 29). However, in May, 1973, the biomass of bladderwort appeared to be exceeding that of the previous year.

During the 1972 growing season, bladderwort was replaced to a large extent by carpet rush in the Control Pond. Since carpet rush formed a dense growth, total macrophyte biomass in the Control Pond remained the same as the previous year.

The Drainless Engine Pond also supported a dense growth of bladderwort at the beginning of the field investigation. Unlike the Control Pond, however, it did not die back over the 1971-72 winter. The biomass declined only slightly and then increased during the following growing season. During the 1972-73 winter, bladderwort decreased only slightly in the Drainless Engine Pond and flourished again during the spring of 1973. It is important to note that the Drainless Engine Pond was an arm of the Control Pond prior to constructing a dike at the beginning of the project.

A second species of bladderwort, Utricularia foliosa (Greater Bladderwort), which was dormant until the Autumn of 1972, began growing in the sublittoral zone of the Drainless Engine Pond. This growth continued throughout the period of treatment.

The Drained Engine Pond initially supported a mixed growth of bladderwort and water mint in the deep-eulittoral and sublittoral zones. Water mint was more abundant in the shallow water and bladderwort the most abundant in the deeper water. Water mint replaced bladderwort during the summer of 1972 in all areas of the Drained Engine Pond except the center, where water mint and bladderwort remained in co-existence. This situation remained constant until the early spring of 1973, when bladderwort began emerging again in the deep-eulittoral zone. During the last month of the study, bladderwort biomass was continuing to increase in preparation for flowering.

The vegetational changes of the Drained Engine Pond and the Drainless Engine Pond followed normal qualitative patterns; that is, species composition, frequency, and distribution followed natural seasonal cycles. However, there was a significant change in the quantitative aspects of biomass in the Drainless Engine Pond. As evidenced in Figures 3,4, and 5, there was clearly an increase in macrophyte biomass in the Drained Engine Pond.

Grassbed Primary Productivity

As presented in Figure 6 and Table 30, grassbed primary productivity among the three ponds ranged from a low of 0.02 g Cm^{-2} day^{-1} in mid-winter to a

Table 29. Species composition of macrophytes observed along a 6 meter transect through the eulittoral zone and into the sublittoral zone in Control Pond, Drained Engine Pond, and Drainless Engine Pond during 1972 and 1973.

	ABUNDANCE[a]														
	CONTROL POND					DRAINED ENGINE					DRAINLESS ENGINE				
	Apr 1972	June 1972	Sept 1972	Dec 1972	Mar 1973	Apr 1972	June 1972	Sept 1972	Dec 1972	Mar 1973	Apr 1972	June 1972	Sept 1972	Dec 1972	Mar 1973
TERRESTRIAL															
Cyperus esculentus[b] (Yellow Nutsedge)		2													
Eriocaulon decangulare (Pipewort)	2	3	14	1		4	3	1			8	12	2		10
Hydrocotyle umbellata (Pennywort)	6	4			10	1	1	1			9	9	7	6	10
Eupatorium capillifolium (Dogfennel)					4					5					1
Hypericum cistifolium (St. John's Wort)															1
EMERGENT															
Fuirena scirpoides (Umbrella-grass)		5						1			7				
Leersia hexandra (Cypress Grass)	9	13	18	26	4	4	38	19	4	5	16	55	20	11	63
Nuphar advena (Yellow Water Lily)						2			1					1	
SUBMERSED															
Ludwigia palustris (Water Purslane)			1					1			1			1	
Mayaca fulviatilis (Bog-moss)					1	1					7	1			
Hydrotrida caroliniana (Water Mint)	9	2				32	68	91	134	42					
Utricularia floridana (Bladderwort)	35	3	3	5		38	24	1	2	1	54	40	64	108	61
BENTHIC MATS															
Juncus repens mat[c] (Carpet Rush)	61	24	33	56	56	5		14	2	22	6	4	18		
Oedogonium-Spyrogyra Mougeotia Algal Mat												56			
Devoid of Vegetation[d]		23	9	2	2	2	3	4	4	9	4	4	3	2	5

[a] Abundance is based on the number of individuals touching points along a transect at 10cm intervals. The transect was 6 meters long and located on a straight line bisecting the pond center originating at the shore.

[b] *Cyperus* through *Utricularia*: Number of individuals per transect.

[c] *Juncus* and Algal Mats: Number of points mats were found per transect.

[d] Number of points at which no vegetation was found.

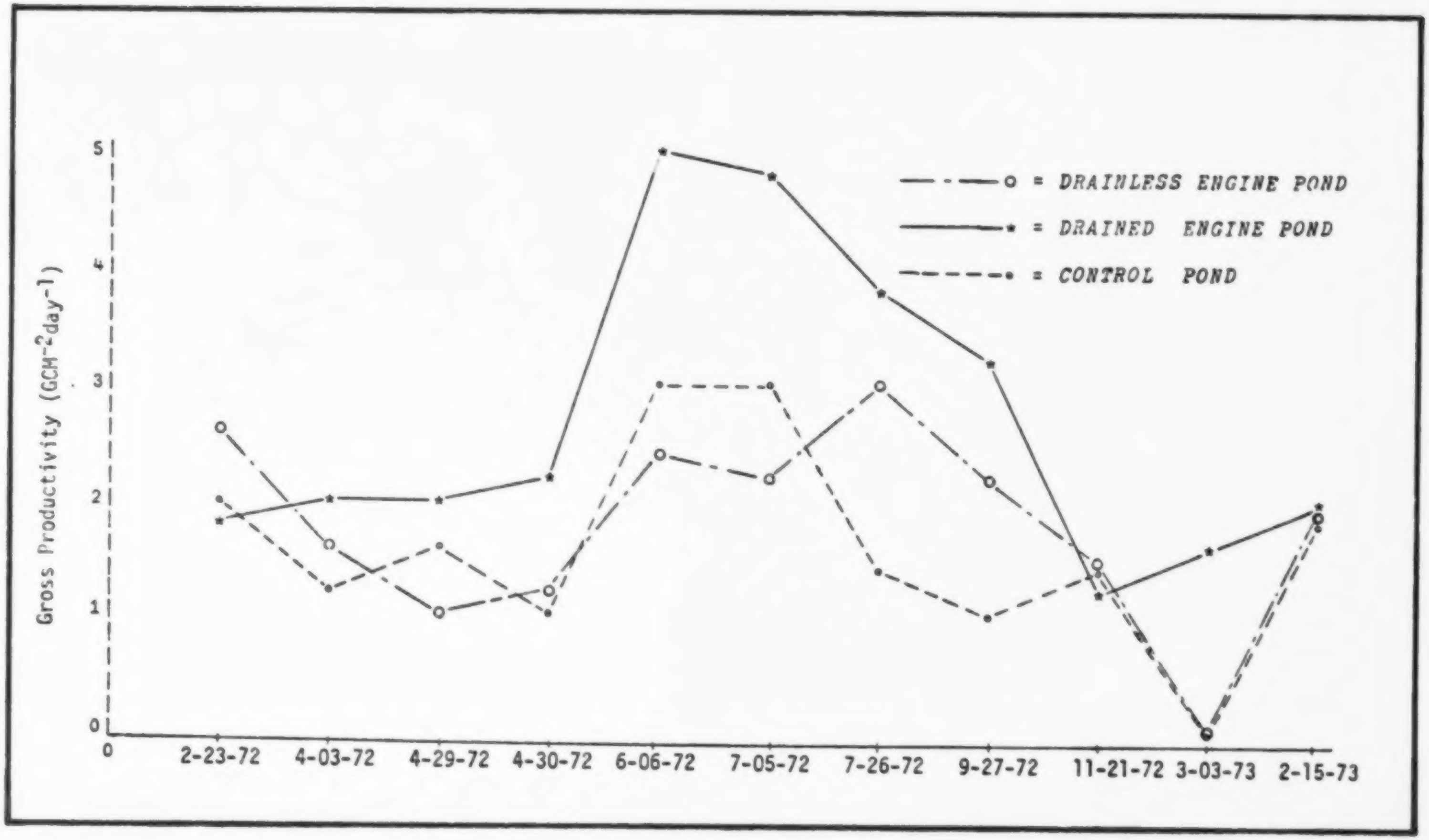

Figure 6. Gross productivity of the grassbed community in the sublittoral zone in the three test ponds.

Table 30. Gross primary productivity of the grassbed community measured in duplicate at monthly intervals in the deep-eulittoral zone in each of the three ponds studied during the second fiscal year.

Date	Primary Productivity (gC $m^{-2}day^{-1}$)[a]					
	Drainless Engine Pond		Drained Engine Pond		Control Pond	
	Sample No. 1	Sample No. 2	Sample No.1	Sample No. 2	Sample No. 1	Sample No. 2
2/23/72	2.31	2.83	1.65	1.76	1.96	1.87
4/03/72	1.24	1.94	2.61	1.26	1.47	1.05
4/29/72	0.58	1.33	2.13	2.01	2.12	0.91
4/30/72	0.62	1.75	2.18	2.31	1.15	0.69
6/06/72	2.27	2.46	5.02	4.97	2.92	3.08
7/05/72	2.33	2.07	4.57	4.89	2.73	3.20
7/26/72	2.33	3.62	4.04	3.39	1.83	1.00
9/27/72	1.84	2.63	3.20	3.01	1.39	0.68
11/21/72	1.03	1.29	1.35	1.21	0.93	1.69
1/03/73	0.08	0.07	1.59	1.60	0.02	0.11
2/15/73	1.71	1.88	2.01	2.02	1.62	1.81
Mean	1.74		2.67		1.56	

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[a] Productivities were measured in a completely submersed air tight clear plastic dome that was embedded in the bottom sediment to form a water tight seal by measuring dissolved oxygen at sunrise, sunset, and again at sunrise during a diel cycle.

maximum of 4.89 g Cm^{-2} day^{-1} in mid-summer. A comparison of mean values observed from 1972-73 shows that the productivity was greatest in the Drained Engine Pond (2.67 g Cm^{-2} day^{-2}) and lowest in the Control Pond (1.56 g Cm^{-2} day^{-1}). An intermediate level of 1.74 g Cm^{-2} day^{-1} was noted in the Drainless Engine Pond. Results of pooled sample t-tests are given below in Table 31.

Table 31. Comparisons of average grassbed productivity between ponds during treatment using pooled sample t-tests and the 95 percent confidence interval.

Null Hypothesis (Ho)	Significance
Ho: Drainless Engine Pond = Control Pond	N.S., Accept Ho
Ho: Drained Engine Pond = Control Pond	.05, Reject Ho, Drained > Control
Ho: Drained Engine Pond = Drainless Engine Pond	.05, Reject Ho, Drained > Drainless

As would be expected, productivity varied in each pond over the months and seasons (Table F4 and F5). In general, productivity was greatest in June and July, regardless of treatment and dropped sharply in January for the Control and Drainless Engine Ponds (but increased in January for the Drained Engine Pond). The Drained Engine Pond in turn had its lowest productivity in December.

Two-way analyses of variance were performed to measure the joint effects of treatment and month (or season) on productivity (Tables F6 and F7). It appears therein that significant interaction between the temporal variables and treatment is occurring. Hence the treatments must be compared for specific months.

Table F8 summarizes the treatment comparisons for each month. It was found that significant differences (99 percent confidence level) among treatments occurred in January, April, June, July and September. In each case the Drained Engine Pond had the highest productivity, with the next highest being the Drainless Engine Pond in all these months except June.

Enrichment experiments were conducted in the Control and Drained Engine Ponds to assay the grassbed community for carbon as a limiting factor during the fall season (Tables 32 and 33). As pH was low and there was the probability of a non-carbonate buffer system, carbon dioxide was suspected to be a limiting factor in grassbed primary productivity. Five levels of a carbonate solution (0.5-10 mg/1) were added to individual domes by capillary tubes. Grassbed primary

Table 32. Effects of carbon dioxide enrichment on gross primary productivity in the grassbed communities of the deep-eulittoral zones of the Control Pond on November 2, 1972 and the Drained Engine Pond on October 26, 1972.

Carbon[a] Enrichment (ppm)	Primary Productivity (gC m^{-1} day^{-2})					
	Drained Engine Pond			Control Pond		
	Pg(ambient[c])	Pg(treatment[d])	ΔPg(effect[e])	Pg(ambient[c])	Pg(treatment[d])	ΔPg(effect[e])
0.0	3.36	3.38	0.02	1.36	1.15	-0.21
0.5	2.25	2.80	0.55	1.21	1.38	0.17
1.0	1.84	2.65	0.81	1.13	1.23	0.10
2.0	1.96	2.32	0.36	1.35	1.45	0.10
5.0	2.58	2.53	-0.05	1.38	1.424	0.116
10.0	2.57	3.42	0.85	1.60	1.81	0.21
Treatment Mean	2.24	2.74	0.46	1.33	1.42	0.09

[a] Carbon was continuously and uniformly added to the clear plastic domes over a period of about 6 hours beginning at sunrise. The treatment levels reported above are the total amounts of carbon added to the domes.

[b] Productivities were measured in a completely submersed airtight clear plastic dome that was embedded in the bottom sediment to form a water tight seal by measuring dissolved oxygen at sunrise, sunset, and again at sunrise during a diel cycle.

[c] Ambient or baseline productivites were measured on the day prior to enrichment in the Control Pond and the day following enrichment in the Drained Engine Pond.

[d] Pg (treatment) = productivities on the day of enrichment.

[e] ΔPg (effect) = Pg (treatment) - Pg (ambient).

Table 33. Incident solar radiation and water temperature measured during the carbon enrichment experiments in the Control Pond and the Drained Engine Pond.

Date	Pond	Light (Kcal m^{-2} day^{-1})[a]	Temperature (°C)[b] Dawn	Temperature (°C)[b] Dusk
10/25/72	Drained-engine	1.77	24.0	25.0
10/26/72	Drained-engine	1.31	22.5	25.0
11/01/72	Control	1.92	23.5	26.0
11/02/72	Control	2.12	24.0	26.0

[a] Light was measured with a pyrheliometer next to the Control Pond and on the dock of the Drained Engine Pond.

[b] Temperature was measured with a YSI thermistor.

Table 34. Comparison of grassbed productivity within the Drained Engine and Control Ponds before and during carbonate enrichment using two-way ANOVA and the 95 percent confidence interval.

Null Hypothesis (Ho)	Pond	Significance
Pg before enrichment = Pg during enrichment	Drained Engine Pond	.05, Reject Ho. Pg during enrichment is greater than Pg before enrichment.
Pg before enrichment = Pg during enrichment	Control Pond	N.S., Accept Ho

productivity was measured before and after the addition of carbonates and compared to a control. Carbonate enrichment significantly increased productivity in the Drained Engine Pond by approximately 20 percent (Table 34). No significant differences in productivity were effected by adding carbonates to the Control Pond although increases averaging eight percent were recorded in four of the five domes. When compared, the Drained Engine Pond had much greater initial biomass than the Control Pond. The project was terminated before additional carbonate enrichment experiments could be run during the summer growing season.

Periphyton

Periphyton biomass and growth rate (Table 35) were measured throughout the study. Daily growth rates, expressed as grams of organic matter produced per square meter per day, ranged from less than 0.01 to 0.12 during the

Table 35. Periphyton biomass and growth rates of the three test ponds measured during the periods before treatment and during treatment.

Incubation		Drainless Engine Test Pond			Drained Engine Test Pond			Control Test Pond		
Date	No. of Days	DW[a]	AFDW[b]	GR[c]	DW	AFDW	GR	DW	AFDW	GR
8/19-09/02/71	14	1.07	0.46	0.03	1.87	1.70	0.12	NM	NM	NM
9/10-09/24/71	14	2.02	0.94	0.07	1.66	1.21	0.09	NM	NM	NM
10/30-11/19/71	20	1.24	1.01	0.05	3.16	1.84	0.09	1.23	0.93	0.05
12/02-12/23/71	21	1.15	0.58	0.03	0.84	0.43	0.02	1.54	1.11	0.05
January, 1972	-	NM[d]	NM	NM	NM	NM	NM	NM	NM	NM
2/04-02/25/72	21	0.64	0.64	0.03	2.15	2.15	0.10	0.35	0.35	0.02
3/07-03/28/72	21	1.51	1.16	0.06	0.87	0.17	0.01	1.68	1.17	0.06
4/07-04/28/72	21	0.91	0.46	0.02	1.40	0.96	0.05	1.26	0.55	0.03
5/11-06/02/72	22	1.46	1.03	0.05	2.46	2.00	0.09	2.03	1.46	0.07
6/14-07/05/72	21	0.98	0.84	0.04	2.01	1.49	0.07	3.97	1.78	0.08
7/12-07/26/72	14	0.55	0.37	0.03	2.03	1.23	0.09	1.34	0.95	0.07
7/26-08/10/72	15	1.51	0.97	0.06	1.84	1.46	0.10	1.29	0.86	0.06
8/24-09/07/72	14	1.35	1.17	0.08	0.65	0.53	0.04	1.29	1.01	0.07
9/07-09/20/72	13	1.55	0.64	0.05	0.81	0.51	0.04	1.13	0.55	0.04
10/13-10/27/72	14	0.96	0.58	0.04	0.46	0.20	0.01	1.23	0.82	0.06
11/13-11/27/72	14	0.77	0.61	0.04	0.76	0.53	0.04	1.77	1.20	0.09
12/04-12/18/72	14	1.21	0.95	0.07	1.06	0.72	0.05	0.99	0.67	0.05
12/18-01/03/73	16	1.10	0.86	0.05	0.92	0.58	0.04	1.63	1.02	0.06
1/17-01/30/73	13	0.29	0.13	0.01	NM	0.00	NM	0.56	0.19	0.01
1/30-02/13/73	14	0.36	0.15	0.01	0.54	0.34	0.02	0.46	0.20	0.01
2/13-02/27/73	14	0.39	0.18	0.01	0.07	0.05	0.09	0.45	0.20	0.01
2/27-03/13/73	14	0.49	0.34	0.02	0.84	0.47	0.03	0.22	0.17	0.01
3/13-03/27/73	14	1.18	0.41	0.03	1.52	NM	NM	1.30	0.57	0.04
Mean (Average)				0.04			0.06			0.05

[a] DW : Dry Weight; grams per square meter.

[b] AFDW: Ash Free Dry Weight; grams per square meter.

[c] GR : Growth Rate; grams of organic hydrocarbons produced per square meter per day.

[d] NM : Not Measured

course of this study. The highest single daily growth rate occurred in September in the Drained Engine Pond (0.12 g/m^2). In general, periphyton growth rates were highest during the summer months and lowest during the winter (Figure 7).

A pooled sample t-test was used to determine significance of variations in the data. This test compared productivity values from the combinations of Control and Drained Engine Ponds, Control and Drainless Engine Ponds, Drained and Drainless Engine Ponds, and Control, Drained and Drainless Engine Ponds. Although the Drained Engine Pond showed highest single daily growth rates and a higher yearly average, the variations in organic productivity between the three study ponds was not significant at the 95 percent level of confidence (Table 36).

DISCUSSION

Evaluation of Methods

The ecological importance of the macrophytes and their response to treatment was not realized before the project was started. The most significant shortcomings of the macrophyte study were the lack of baseline data and treatment data. Statistically, the sample size and frequency of sampling were inadequate and the data were difficult to interpret. Another short-coming was the method used to measure the biomass. Biomass was determined volumetrically (expressed as organic content). Due to differences in water content between various species of macrophytes, as well as growth stages, conclusions drawn from the comparison of biomass can be only suggestive.

Periphyton studies for at least the past 50 years have used glass slides. The advantages of microscopic slides include ready availability, a transparent surface for the viewing of periphyton cultures intact through a microscope, ease of sampling rack design (including several racks actually marketed for this purpose), and ready comparison with a large number of previously published studies. The glass slide is undoubtedly the most commonly employed artificial substrate in periphyton research.

With any artificial substrate, the possibility exists that the resulting growth has been influenced by a property of the substrate. Evidence has been gathered that surface texture and color affect resultant diatom populations. Glass may be a less preferable substratum for certain algae, particularly blue-greens (44).

Growth rate estimates made from organic carbon determinations of periphyton represent estimates of net productivity. True net productivity is equal to gross productivity minus maintenance (respiration) losses. The net productivity calculated by the method employed in this study reflects other losses also. These include the effects of grazing and predation, and death and decomposition. The latter is a function of the turnover rate of the components of the periphyton (56). For

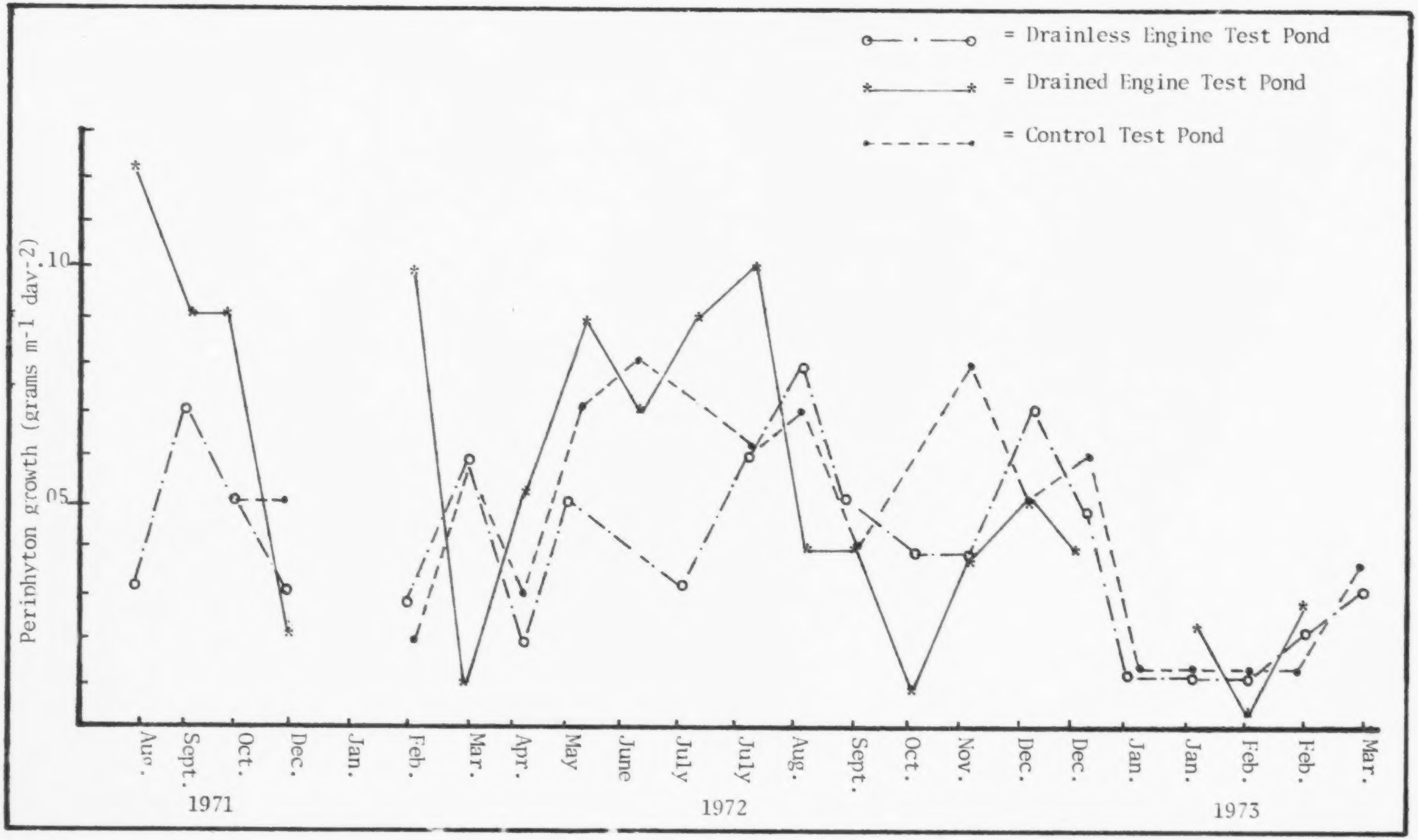

Figure 7. Periphyton growth rates of the three test ponds, as estimated from growth on glass slides.

Table 36. Comparison of average periphyton growth rates between the three test ponds during treatment using one-way ANOVA and pooled sample t-tests (95 percent confidence interval).

	August 19, 1971 through February 25, 1972		March 7, 1972 through January 3, 1973		January 17, 1973 through March 27, 1973		August 19, 1971 through March 27, 1973	
Null Hypothesis; Biomass of: $Pond_1 = Pond_2$ ($= Pond_3$)	Calculated[a] F - Value	Treatment of Null Hypothesis	Calculated[a] F - Value	Treatment of Null Hypothesis	Calculated[a] F - Value	Treatment of Null Hypothesis	Calculated[a] F - Value	Treatment of Null Hypothesis
Control, Drained	1.4 (6.0)	Accept Ho	0.6 (4.30)	Accept Ho	0.2 (5.99)	Accept Ho	0.2 (4.2)	Accept Ho
Control, Drainless	0.3 (6.0)	Accept Ho	0.2 (4.30)	Accept Ho	0.1 (5.32)	Accept Ho	0.6 (4.1)	Accept Ho
Drained, Drainless	1.1 (5.3)	Accept Ho	0.7 (4.30)	Accept Ho	0.1 (5.99)	Accept Ho	1.2 (4.1)	Accept Ho
Drained, Drainless, Control	1.1 (4.1)	Accept Ho	0.6 (3.30)	Accept Ho	0.9 (4.10)	Accept Ho	0.7 (3.2)	Accept Ho

[a] Values within parentheses are standard F-values for the 95% confidence level.

this study it was assumed that periphyton in the three treatment ponds were essentially similar in composition and that the consumption and turnover rates within each of the three ponds were of the same order of magnitude. Growth rates thus calculated are presumed to reflect any actual differences in productivity between the ponds.

The techniques used in this study for measuring primary productivity of the grassbed community has been criticized by several investigators, most notably Wetzel (56). Studies conducted by Hartman and Brown (15) show that oxygen produced by vascular aquatic plants during photosynthesis is nominally stored in intercellular lacunae (open spaces between cells) before release into the water. A rapid diurnal accumulation of oxygen in the lacunae occurs with a slow diffusion into surrounding water. A similar and opposite fluctuation of carbon dioxide produced by respiration was also observed. This is because gas exchanged between intercellular lacunae and the pond water is determined by normal gas diffusion rates through osmotic membranes, which is a slow process.

The data, although biased by these considerations, can nonetheless be used as relative estimates among ponds. The error can be assumed to be a rate dependent upon productivity and therefore self-cancelling in comparisons among ponds. This is supported by the reproducibility of results during sampling in April, 1972, and during the carbon enrichment studies.

Macrophytes

The two most important plant species as indicators of change in the test ponds were water mint (Hydrotrida caroliniana) and bladderwort (Utricularia floridana). In all three ponds, bladderwort biomass peaked in the early summer with the culmination of flowering (June-July). During the winter, bladderwort biomass declined and the subterranean components entered a dormant state in Control Pond and the Drained Engine Pond. However, the standing crop of bladderwort remained dense in the Drainless Engine Pond the year around. To test the hypothesis that it was the Control Pond and not the Drainless Engine Pond that was acting out of the ordinary, other ponds in the general area were visually checked throughout the study. In those that did not dry up during 1972, bladderwort exhibited the same pattern as that in the Control Pond. Therefore, its presence in the Drainless Engine Pond was possibly associated with treatment.

Water mint continued to produce throughout most of the year with the exception of winter months, and flowered during the early fall. It was present in large quantities in the Drained Engine Pond and small quantities in the Drainless Engine Pond, the Control Pond, and all of the surrounding ponds. In addition, the biomass of water mint increased with treatment in the Drained Engine Pond.

Therefore, the elevated growth of water mint in the Drained Engine Pond is possibly associated with treatment.

Dependent Components

There are various components of the grassbed community which are directly dependent upon the quantity and composition of the aquatic macrophytes. These include periphyton, herbivores, carnivores, and detritivores. Periphyton requires a solid substrate for support; herbivores directly consume the foliage; carnivores consume herbivores; and detritivores consume excess litter.

The periphyton removes nutrients from the water, thus increasing energy and nutrient utilization within the community and aiding in the prevention of phytoplankton blooms. Periphyton may also have an inhibitory effect on macrophytes by physically blocking sunlight.

Periphyton production showed no significant difference among the three treatment ponds as estimated from growth on glass slides. This method, however, indicates only an estimation of growth potential on an artificial substrate, as actual periphyton production is a function of natural substrate availability. In the treatment ponds this requirement is filled by aquatic macrophytes. Periphyton biomass and production, therefore, is a proportionate function of macrophytic surface area. Species composition is also a major factor, as surface area differs among species. Bladderwort and water mint, tall and submersed plants, which dominated the Drained and Drainless Engine Ponds, afford more available substrate than does carpet rush, a benthic mat, which is the dominant macrophyte in the Control Pond. Bladderwort, which has close, finely-divided leaves, supports periphyton not only on its leaves and stems but also suspended between them. Therefore, the Drainless Engine Pond, where bladderwort dominates, may carry a greater standing crop of periphyton than the Drained Engine Pond. Consequently, the Drained and Drainless Engine Ponds may support a greater biomass of periphyton than the Control Pond.

Herbivores and detritivores provide several important feedback energy flows to the macrophytes. As herbivores graze, they stimulate plant growth in two ways. First, in eating the older leaves, herbivores stimulate the plants to produce more photosynthetic surfaces (leaves). Secondly, many stems are broken from the plant during grazing, and these drift to new areas where they can colonize. Detritivores function as the final link in the nutrient cycle. They decompose organic matter into inorganic constituents which are then available to the plants.

Cover and nesting habitat for consumers and detritivores is also provided by macrophytes. Increased amounts of cover, such as that provided in the Drained and Drainless Engine Ponds, decrease mortality rates of herbivores and immature carnivores. This decreases energy losses from the system and tends to increase animal biomass. Adult carnivores such as the largemouth bass, however, are conversely affected, as they must work harder to catch their prey. This tends to produce smaller game fish. For this reason, the Control Pond is expected to provide better bass fishing.

The above considerations concerning food and cover availability leads to the conclusion that, since the Drained Engine Pond has the greatest plant biomass it also has the potential for the greatest animal biomass on a per unit surface area basis. Further, since the plant biomass of the Drainless Engine Pond is greater than that of the Control, it also has the potential for a greater animal biomass per unit area.

Grassbed Productivity

Productivity and biomass are integrally related in the three treatment ponds, as biomass is a product of production, and the rate of production, is in part, dependent upon the amount of producing biomass present. It is therefore understandable that the two parameters were significantly highest in the same pond (Drained Engine Pond). Further, even though there was no significant difference between the Drainless Engine Pond and the Control Pond for either parameter, they were both slightly higher in the Drainless Engine Pond.

Observations of gross macrophyte structure in the Control and Drainless Engine Ponds reveal that during most of the study, the macrophytes of the Control Pond, mostly carpet rush, occupied only the benthic component of the water column, whereas in the Drainless Engine Pond the dominant macrophyte, bladderwort, occupied nearly the entire water column. This greater volume of foliage could be the reason for the slightly higher productivity in the Drainless Engine Pond.

During the 1972 growing season, primary productivity in the grassbed community appeared to be stimulated by outboard motor operation. Since it is possible that CO_2 in the grassbed community becomes limiting at various times during the growing season, an additional CO_2 input from outboard motor operations could increase production.

Carbon dioxide (in carbonate form) was added to the grassbed communities of the Drainless Engine Pond and the Control Pond in an effort to determine if CO_2 was actually limiting. This experiment was conducted during the autumn when the grassbeds were approaching the dormancy period and therefore this period does not represent a time when treatment effects could be readily observed. Nevertheless, gross productivity did increase in the more productive pond after the CO_2 level was raised. Consequently, it is concluded that CO_2 limiting conditions can occur in the rooted aquatic plant communities and that increased availability of CO_2 during these periods may increase grassbed productivity.

Carbon Dioxide Pathways

An energy and materials flow diagram is one tool which can be used to illustrate and describe the effects of carbon dioxide enrichment in the test ponds. These diagrams employ the energetics terminology developed by H. T. Odum. Their advantage is that the primary energy and materials flows can be readily observed and comprehended by the usage of a single illustration.

As shown by the materials and energy flow diagram in Figure 8, carbon dioxide enters the Drainless Engine Pond from the atmosphere, the outboard engine, and from plant and animal respiration. The dissolved CO_2 is then taken up by the plants and follows a cycle similar to that of the Control Pond.

The outboard engine conceivably alters the magnitude of several of the normal CO_2 pathways by mechanical mixing of the water. First, this mixing and stirring (advection and convection) allows more CO_2 to be dissolved into the water, and secondly it circulates the water surrounding the plants, thus transporting CO_2 directly to the plants. This could result in bladderwort growing more densely during the growing season. Perhaps increased advection is the most significant effect of treatment, as not only CO_2 but other chemical constituents are made available to the grassbed community through advection.

Due to the alternating growth peaks of bladderwort and water mint, and to the drained character of the outboard engines used in this pond, CO_2-carbon materials circuit of the Drained Engine Pond (Figure 9) is more complex than the other two ponds. However, despite the increased number of paths and compartments, the flows should be essentially the same.

SUMMARY

1. The Control Pond, as with the other non-stressed ponds in the area, decreased in total biomass from the winter of 1971-72 until the spring of 1973, when it began increasing.

2. Carpet rush replaced bladderwort in the shallow margins of the Control Pond, maintaining a steady biomass in the shallow-eulittoral zone.

3. The biomass of the Drainless Engine and Drained Engine Ponds increased substantially, the latter having the greatest increases.

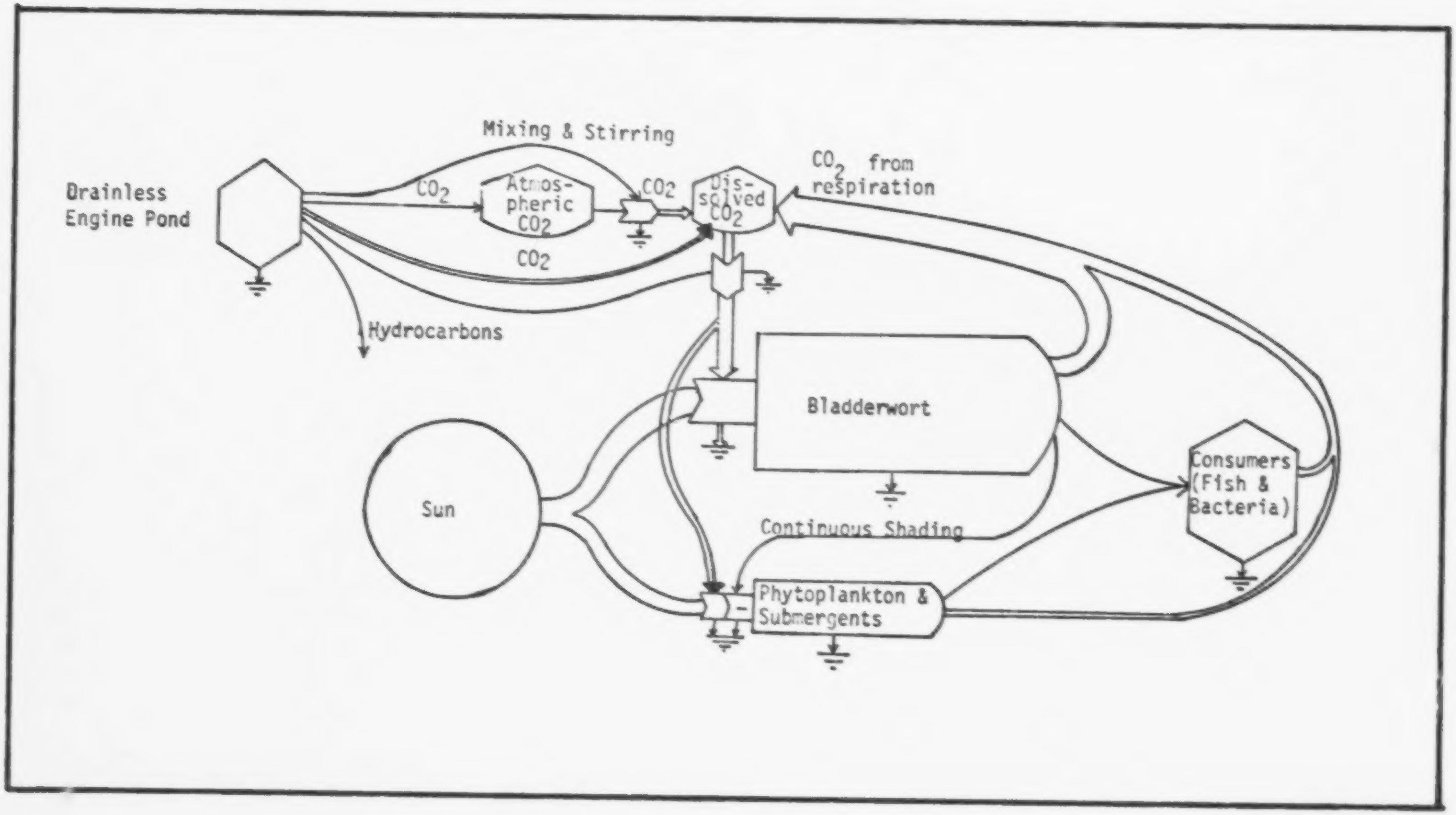
Drainless Engine Pond
Mixing & Stirring
CO_2
Atmos-pheric CO_2
CO_2
Dis-solved CO_2
CO_2 from respiration
CO_2
Hydrocarbons
Bladderwort
Sun
Continuous Shading
Phytoplankton & Submergents
Consumers (Fish & Bacteria)

Figure 8. CO_2 carbon materials circuit of the eulittoral zone of the Drainless Engine Pond.

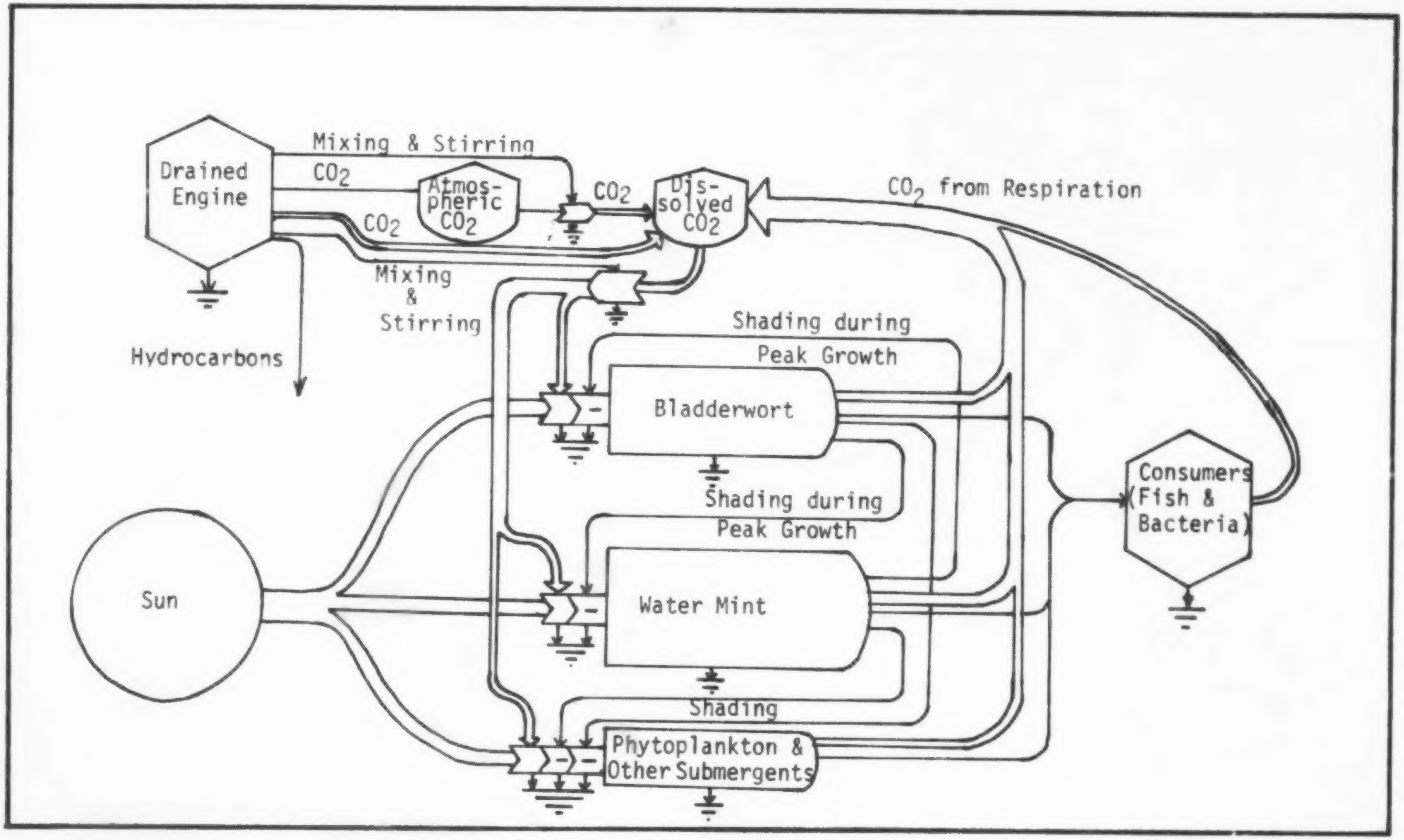
Drained Engine
Mixing & Stirring
CO_2
Atmos-pheric CO_2
CO_2
CO_2
Dis-solved CO_2
CO_2 from Respiration
Mixing & Stirring
Hydrocarbons
Shading during Peak Growth
Bladderwort
Shading during Peak Growth
Sun
Water Mint
Consumers (Fish & Bacteria)
Shading
Phytoplankton & Other Submergents

Figure 9. CO_2 - carbon materials circuit of the eulittoral zone of the Drained Engine Pond.

4. Water mint replaced bladderwort in the Drained Engine Pond throughout the 1972 growing season. However, bladderwort was re-establishing itself at the time (May, 1973) the study was terminated.

5. During the growing season, primary productivity of the grassbed community is limited by carbon dioxide. This limitation is a natural feedback control feature and is affected by outboard motor operation at the treatment levels employed.

6. A carbon enrichment experiment conducted during November showed that the pond with the highest grassbed productivity was carbon limited since enrichment with carbon dioxide significantly increased grassbed productivity. When conducted in the pond that had the lowest productivity, the same experiment showed that there was an eight percent rise in productivity in four out of five tests. The exhibited increase was not statistically significant due to masking by natural variability and the significantly lower demand for carbon dioxide during the fall experimental period.

7. Three conditions cause carbon dioxide to be limiting to the grassbed community: 1) high grassbed productivity, averaging 3 g Cm^{-2} day^{-1} during the summer; 2) low concentration of total inorganic carbon, averaging 0.6 g Cm^{-2}; and 3) little or no mass transport of carbon dioxide to the rooted aquatic vegetation.

8. Motor operation increased the availability of carbon dioxide to the grassbed community by stirring and mixing the pond and by emitting carbon dioxide into the pond.

9. The level of total inorganic carbon in the limnetic zone was found to be significantly greater in the Drained and Drainless Engine ponds than in the Control Pond. These differences are attributed to the operation of outboard motors.

10. Outboard motor operation probably increased grassbed productivity. The Drained Engine Pond exhibited a significantly higher (approximately 100 percent) grassbed productivity than the Control Pond. The grassbed productivity of the Drainless Engine Pond, although not statistically significant, averaged approximately 10 percent higher than the Control Pond.

11. Although tests using glass slide substrates showed no significance between ponds, the total standing crop of periphyton could be greater in the Drained and Drainless Engine Ponds than in the Control Pond because of the greater standing crop of macrophytes.

12. Because of the large substrate area associated with the macrophytes in each pond, a significant proportion of the grassbed productivity could be the result of the periphyton component.

13. Though evidence indicating increased plant production due to increased availability of carbon dioxide was found in the soft water southern test lakes, such an affect on waters with carbonate-bicarbonate buffer systems which is typical of most American waters, would likely be unnoticeable under normal boating regimes.

SECTION VII

PHYTOPLANKTON

Like rooted aquatic vegetation, phytoplankton play an important role in the production of basic food for their ecosystem. Although the standing crop of phytoplankton may be less than that of the macrophytes, the phytoplankton may still be more important as the primary source of organic matter to the upper trophic levels. In clear shallow lakes, in which the light intensity at bottom depths is high, the opposite may be true. Many of Florida's lakes are shallow and quite clear allowing for a luxurient growth of macrophytes. Thus the phytoplankton most likely play a supporting role in the production of organic matter within the three treatment ponds.

Aside from their ecological role in the aquatic community, phytoplankton may directly affect man and his economy when certain species are given conditions which allow for their rapid multiplication. When an algae responds to these conditions, it is said to be "blooming." Blooms usually occur as a result of an increase in the nutrient levels within a body of water, giving species which can most effectively exploit these nutrients an opportunity to greatly increase their numbers. When blooms of certain species occur, the result may vary from the water acquiring an unpalatable taste or odor to the degradation of the ecosystem.

In this study, several shallow and clear Florida lakes were examined to determine, in part, the effect of outboard motor emissions on phytoplankton. In a report distributed by the Marine Exhaust Research Council (39), phytoplankton were considered to be poor indicators of pollution by outboard motor emissions. Previous outboard emissions studies (24) determining the effects upon phytoplankton biomass have suggested that there is no effect at normal levels of motor operation. Kumar (41) investigated the effect on phytoplankton productivity. His tests were carried out by using simulated motor boating conditions, however, he could not measure any observable effects of the emissions on phytoplankton productivity.

FIELD AND LABORATORY PROCEDURES

Whole water plankton samples of one-liter volume were collected and preserved in 3 percent formalin for the microscopic examination of species composition and population densities. All samples were composites of surface and bottom waters taken from the limnetic zone at each pond. Sampling was conducted at monthly intervals during 1971, twice a month during 1972, and three times a month during 1973.

Sample analyses involved several steps. Identifications and counts were performed according to Lackey's microtransect technique during 1971 and 1972 (25). During 1973, the Utermöhl settling technique utilizing the inverted microscope was used (53). Taxonomic determinations were carried to the species level in most cases. References used for indentification were primarily those of Smith (45), Prescott (37 and 38), Whitford and Schumacher (57), Drouet and Dailey (10), and Ward and Whipple (55). In an effort to compare the structure of the various plankton communities within the three ponds, the Shannon-Weaver species diversity index was utilized (36).

Chlorophyll a levels, an estimate of phytoplankton biomass, were measured in composited samples of surface and bottom water collected from the limnetic zone in each pond. Analysis was performed using the fluorometric procedure described by Lorenzen (28). Samples were collected at least once per month.

Phytoplankton productivity was measured in accordance with the technique outlined by Strickland and Parsons (49). Analysis was conducted in situ in the surface and bottom layers at monthly intervals during 1971. The C^{14} productivity method was replaced with the oxygen productivity method in 1972 (5). Field procedures for the oxygen method were similar to those of the C^{14} method. Measurements were taken at monthly intervals in the surface water of the limnetic zone in each pond. Replicate analyses were occasionally performed to determine experimental error and subsample analyses were occasionally performed to determine spatial differences in the surface water.

RESULTS AND DISCUSSION

Species Composition

Results of the taxonomic study found the blue-green algae (Cyanophyceae) to be the most abundant group of organisms within all three treatment ponds (Appendix G). The Cyanophyceae were comprised of 20 species, 18 of which occurred in Control Pond, 13 in the Drained Engine Pond, and 14 in the Drainless Engine Pond.

The most abundant organism observed throughout the study was the blue-green algae, Anacystis marina (Appendix G). This small blue-green algae (2 X 0.5 microns) reached greatest abundance on March 26, 1973 in the Drainless Engine Pond where it was recorded at 40,000 cells/ml. A. marina was found as a dominant organism in 46 percent of all samples in the Drainless Engine Pond, 35 percent in the Drained Engine Pond, and 33 percent in the Control Pond. Other important blue-green species recorded were: Gloeothece linearis, Polycystis aeruginosa, Merismopedia sp. and Anabaena sp. Table 37 summarizes the percent occurrence of the blue-green algae collected in the three ponds.

The most diverse group of phytoplankton observed were the green algae, (Chlorophyceae). A total of 39 species were observed in the

Table 37. Percent occurrence[a] of blue-green algae within the three test ponds.

Genera	Drainless Engine Pond	Drained Engine Pond	Control Pond
Anacystis marina	46	35	33
Gloeothece linearis	18	8	5
Polycystis aeruginosa	3	8	8
Merismopedia punctata	15	3	23
Anabaena sp.	28	28	21
Anabaenopsis sp.	5	3	10
Microcoleus sp.	3	0	13
Merismopedia glauca	3	5	3

[a] To compute percent occurrence divide the number of samples in which the selected species was observed by the total number of samples collected and multiply by 100.

Drainless Engine Pond, 38 species in the Drained Engine Pond, and 40 species in the Control Pond. Filamentous green algae were comparatively sparse within the plankton community. Common filamentous genera were Mougeotia sp.and Oedogonium sp. Nonfilamentous green algae, including the Mesotaeniaceae and Desmidiaceae, were much more commonly observed. The most common nonfilamentous greens were Oocystis, Sphaerocystis, Asterococcus, and Planktospheria, and the desmids were Staurastrum, Euastrum, Cosmarium, Cylindrocystis, Desmidium, Closterium, and Arthrodesmus.

In general, the green algae were low in species abundance as most species were recorded as rare (1-5 cells/ml). The ten most frequently observed chlorophyceans are listed in Table 38 in their percent occurrence within all plankton samples collected from the three test ponds.

During the course of this study, no large blooms of green algae were observed that could have affected the clarity of the test ponds. Also, no large mats or masses of filamentous species were present, such as massive growths of Spirogyra or Mougeotia (Appendix G, Tables G2 and G4). However, localized algal mats consisting of Spirogyra, and Oedogonium and Mougeotia were common in the shallow eulittoral zone of the three test ponds.

Table 38. Percent occurrence of green algae within the three treatment ponds.

Genera	Drainless Engine Pond	Drained Engine Pond	Control Pond
Oocystis sp.	64	69	41
Staurastrum sp.	43	33	36
Mougeotia sp.	43	33	31
Sphaerocystis sp.	36	43	13
Euastrum sp.	25	17	23
Cosmarium sp.	23	17	23
Asterococcus sp.	20	28	8
Oedogonium sp.	15	10	23
Cylindrocystis sp.	13	8	17
Planktospheria sp.	18	12	5

Another characteristic component of Florida acid-soft water lakes are the golden-brown algae (Chryosophyceae). A total of nine species were observed during the course of the study with seven species occurring in the Drainless Engine Pond, four in the Drained Engine Pond, and eight in the Control Pond. Common members of this group are: Dinobryon sertularia, Synura uvella, Mallomonas caudata, M. akrokomas and Botryococcus braunii. Table 39 presents a list of common species and their percent occurrence within all plankton samples in each test pond. It should be noted that Synura uvella was more prevalent in the treated ponds than Control Pond (Appendix G, Table G5).

A total of seven species of dinoflagellates (Dinophyceae) were recorded throughout 1971-1973, with five species present in the Drainless Engine Pond, six in the Drained Engine Pond, and six in the Control Pond. Dinoflagellates were represented most frequently in the plankton community by Peridinium cinctum and P. umbonatum. No significant trends were observed in the distribution of common species within the three treatment ponds with the exception of Ceratium cornutum which was more prevalent in the Control Pond than in the two treated ponds. Table 40 lists the percent occurrence of common dinoflagellates observed in the three ponds. Supporting data are reported in Appendix G (Table G6).

Table 39. Percent occurrence of Chrysophyceae in the three treatment ponds.

Species	Drainless Engine Pond	Drained Engine Pond	Control Pond
Dinobryon sertularia	51	51	56
Synura uvella	44	31	13
Mallomonas caudata	20	17	15

Table 40. Percent occurrence of dinoflagellates in the three treatment ponds.

Species	Drainless Engine Pond	Drained Engine Pond	Control Pond
Peridinium cinctum	51	54	41
P. umbonatum	46	26	36
P. wisconsinense	10	5	15
Ceratium cornutum	2	8	23
Glenodinium gymnodinium	0	2	2
Gymnodinium sp.	8	10	10

The diatoms (Bacillariophyceae) were rare within the treatment ponds as only 3 of the 15 diatoms observed were planktonic species. Low numbers of diatoms have also been reported in a study of two acid-soft water lakes (27). It is considered that the low silica levels occurring within these ponds may account for the small populations of diatoms.

Other important groups were: the Cryptophyceae, represented by two genera, Cryptomonas and Rhodomonas; the chloromonads, represented by the acid water species, Gonyostomum semen; and the euglenids, represented by five genera, Euglena, Menoidium, Petalomonas, Peranema and Trachelomonas (Appendix G).

In addition to the phytoplankton, a large number of protozoans were observed within the plankton community (Appendix G). The most abundant group of protozoans were the ciliates. The ciliates were comprised of twelve species with nine occurring in the Drainless Engine Pond, seven in the Drained Engine Pond, and nine in the Control Pond. The most common species of ciliates are listed in Table 41. Other protozoan groups observed were the zooflagellates and rhizopods.

Table 41. Percent occurrence of species of Ciliophora within all plankton samples.

Species	Drainless Engine Pond	Drained Engine Pond	Control Pond
Strombidium sp.	35	53	33
Cyclidium glaucoma	26	26	23
Halteria grandinella	18	20	10

In summary, the total number of species observed in each of the three ponds was similar (Table 42). Likewise, each of the eleven major plankton groups observed exhibited approximately the same number and variety of species. Only a few significant differences in species occurrence were noted between the treated ponds and the control. These are given as follows:

(a) At least 10% higher occurrence in control than treated ponds,

Ceratium cornutum;

(b) At least 10% lower occurrence in control than treated ponds,

Oocystis sp.
Sphaerocystis sp.
Asterococcus sp.
Synura uvella
Peridinium cinctum.

Table 42. Summary of plankton species recorded in Drainless Engine Pond, Drained Engine Pond, and Control Pond during the field investigation.

	Total Number of Species		
Taxon	Drainless Engine Pond	Drained Engine Pond	Control Pond
Cyanophyceae	14	13	18
Chlorophyceae	39	39	40
Chrysophyceae	7	4	8
Dinophyceae	5	6	6
Bacillariophyceae	12	6	9
Cryptophyceae	3	3	3
Euglenophyceae	3	3	4
Chloromonadida	1	1	0
Zooflagellata	4	3	3
Rhizopodea	1	3	2
Ciliophora	9	7	9
Total	98	88	102

Indicator Organisms

Pollution tolerant algae when considered alone are not reliable indicators of pollution. However, when a variety of algae are considered as a community, that group may be a reliable index of water quality. Palmer (32) has compiled a list of pollution tolerant algae for which a group of 165 authors have compiled data on the genera and species of the most commonly observed algae found associated with organically enriched waters. It is interesting to note that the genus Anacystis ranks number 19 on the list. However, no mention is made as to the ecology of A. marina, the most abundant organism encountered in all three test ponds. Of significance, A. marina occured with approximately the same frequency in the Control Pond as in the Drained Engine Pond and more frequently in the Drainless Engine Pond. Several species from the genus Anacystis are known to be reliable indicators of organic pollution when found in large numbers, for example, Anacystis aeruginosa and A. montana. It should also be noted that Oocystis ranked number 35 on the list. This genus was a common component of the plankton and occurred more frequently in the treated ponds than in the Control Pond throughout the study. Although Euglena, Oscillatoria and Scenedesmus ranked one, two, and four respectively, their frequencies and distribution within the plankton community were far too low to be considered as indicators of organic pollution.

Cell Density

Phytoplankton cell density ranged 22-40,462 cells/ml and averaged 2820 cells/ml in composite water samples taken from the limnetic zones in the three treatment ponds. These results are comparable to those recorded by Brezonik et al. (3) in a similar acid-soft water lake. Table 43 presents the average and daily cell counts measured in the three treatment ponds.

Seasonally, cell counts were highest in the spring within the Drainless Engine Pond as the mean for all spring data was 7,640 cells/ml (Appendix F, Table F9). However, lowest values were also recorded in the spring in the Control Pond as the seasonal mean was 783 cells/ml. Comparison of mean standing crop values during the fall and winter found them to be similar. Winter mean standing crop values were somewhat reduced in the Control Pond in comparison to the two treated ponds.

Monthly, cell densities were highest in the Drainless Engine Pond as the mean value recorded for all plankton counts during the month of March, 1973 was 10,438 cells/ml. Lowest cell densities were also recorded in March, 1973 from the Control Pond as the mean monthly value for all plankton counts was 170 cells/ml (Appendix F, Table F10).

Two-way analyses of variance were performed to determine the joint effects of season (or months) and treatment on cell densities (Tables F11 and F12). In both cases (month or season) no interaction of these temporal variables with treatments was found. In addition, no overall significant differences were found in average cell densities among the different months (or seasons) or pond treatments.

The above analyses of variance suppose that measurements for the same month in different years (1972 or 1973) can be treated as replicates. In fact there may be significant yearly changes, since the 1973 data indicates significant differences (Table 44) among the average cell densities in the ponds (Drainless Engine Pond = 9680, Drained Engine Pond = 7156, and Control Pond = 2065 cells/ml). Of course, the 1973 data is only representative of portions of the winter and spring of that year. In 1972 data was available for all seasons and no significant treatment differences (Table 44) were found (Drainless Engine Pond = 586, Drained Engine Pond = 1263, and Control Pond = 1254 cells/ml).

Table 43. Cell densities of composite plankton samples (surface and bottom water) taken from the limnetic zone in each of the test ponds during 1971, 1972, and 1973.

STANDING CROP (plankton counts/ml)[a]			
Date	Drainless Engine Pond	Drained Engine Pond	Control Pond
6/28/71	1489	940	1280
7/05/71	2208	9591	9814
7/28/71	1162	2417	660
8/03/71	455	448	1075
8/17/71	477	1519	490
8/27/71	1806	3424	2059
9/15/71	2197	32	1578
9/21/71	1942	4282	5756
10/18/71	5238	4014	3032
11/24/71	642	230	62
12/02/71	719	112	3347
12/15/71	3701	840	409
1/31/72	789	1491	2754
2/10/72	409	2707	6565
3/02/72	145	67	81
3/22/72	106	96	117
4/04/72	101	52	135
4/20/72	156	89	135
May	NM	NM	NM
6/22/72	395	385	159
7/28/72	550	6629	5145
8/07/72	150	22	197
8/17/72	926	1545	195
8/24/72	1533	2705	4030
September	NM	NM	NM
October	NM	NM	NM
11/10/72	660	576	543
11/16/72	89	220	259
12/14/72	69	123	3325
12/19/72	321	2253	88
12/29/72	4735	5055	100
1/04/73	1385	12404	11198
1/15/73	6015	2840	2606
1/22/73	5709	8276	961
2/02/73	3096	14565	1294
2/19/73	2994	5890	1313
2/26/73	24669	1457	729
3/02/73	7395	6310	125
3/09/73	5950	4131	541
3/16/73	8840	15912	81
3/26/73	40463	1189	78
4/02/73	5605	7852	5762
Mean	3443	3159	1859
Std. Dev.	7197.	4060	2662

[a] Analysis from 6/28/71 to 12/29/72 were performed using Lackey's (25) microtransect technique, samples collected from 1/4/73 to 4/2/73 were analyzed utilizing the Utermohl (53) settling technique for the inverted microscope.

NM = Not Measured

Table 44. Comparisons of the standing crops of phytoplankton prior to and during treatment among ponds using one-way ANOVA and pooled sample t-test at the 95 percent confidence level.

Nul Hypothesis (Ho)	Parameter	Time Interval[a]	Significance
Ho: All ponds equal	Total cell count	6/28/71 - 9/21/71	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total cell count	10/18/71 - 12/19/72	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	Total cell count	10/18/71 - 12/19/72	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	Total cell count	12/29/72 - 4/02/73	0.05, reject Ho; Drainless > Control
Ho: Drained Engine Pond = Control Pond	Total cell count	12/29/72 - 4/02/73	0.05, reject Ho; Drained > Control
Ho: All ponds equal	Chlorophyl a	10/21/71 - 3/26/73	0.05, reject Ho; Control > Treated

[a] Prior to treatment

Chlorophyll a

Estimates of standing crop by pigment analysis indicated higher values in the Control Pond as opposed to the treated ponds (Table 45). Standing crop values were found to be quite variable in the test ponds during the study. Chlorophyll a values in the Control Pond averaged 2.0 mg/m^3 throughout 1971-1973, while the Drained and Drainless Engine Pond average 1.8 and 1.5 mg/m^3, respectively. These results are very similar to the chlorophyll a levels recorded by Brezonik et al. (3) in a study of similar lakes.

A one-way ANOVA test at the 95 percent confidence level indicated significantly higher pigment values in the Control Pond than in the two treated ponds which is contradictory to the results of the same test for the 1973 plankton cell counts. When Chlorophyll a was compared with treatment levels in a linear regression, the treated ponds showed no positive correlation (regression coefficients of -0.07 and 0.00). In applying the linear regression test to the Control Pond data, there was a high correlation (0.71) between plankton counts and chlorophyll a but there was no such functional relationship found in either treated pond (.43 and -.05). It should be noted that the correlation between cell numbers and chlorophyll a may be influenced by cell size (54). As for example, Anacystis marina, which was found in higher abundance in the treated ponds, has an extremely small cell size (0.4 μ^3) and most probably a small amount of chlorophyll a. Therefore, many such cells are needed to achieve even a moderate chlorophyll a reading. The presence of small cells of this nature could account for the poor correlation between cell counts and chlorophyll a levels in the treated ponds.

Phytoplankton Species Diversity

Species diversity indices were generally low and exhibited considerable variability (Table 46). During the baseline study (June 1971 to October, 1971), diversity indices in all three test ponds showed similar trends of high variability with ranges below 2.0. Although diversity indices exhibited a slightly higher upper limit of 2.4 during the first 14 months of treatment, the data showed the same variability and similarity of trends. During the last four months of treatment, however, the phytoplankton in the Control Pond increased in diversity to a maximal level of 3.1 while diversities in the two treated ponds declined below average levels. Statistical significance was not observed in diversity indices among the three test ponds during the 1971 baseline study (Table 47). Mean values recorded during this period were: Drainless Engine Pond, 1.33; Drained Engine Pond, 1.10; Control Pond, 1.40. Similarly, the data from 1972 indicated no significant differences in species diversity indices among the three ponds. Mean values recorded during 1972 were: Drainless Engine Pond, 1.67; Drained Engine Pond, 1.35; Control Pond, 1.29. However, significant differences (99 percent confidence level) were observed in the three test ponds in

Table 45. Chlorophyll a levels of composite water samples collected from the limnetic zone of the three ponds during 1971 to 1973.

Collection Date	Chlorophyll *a* (mg/m^3) Drainless Engine Pond	 Drained Engine Pond	 Control Pond
10/21/71	4.2	2.3	3.02
11/11/71	0.8	1.1	3.96
1/17/72	1.8	2.1	2.8
1/31/72	2.2	2.6	.26
2/04/72	1.8	1.9	NM
2/29/72	1.8	1.9	1.9
3/10/72	1.8	1.8	2.0
3/22/72	2.1	2.0	1.8
4/03/72	2.1	2.1	1.8
4/19/72	1.8	2.1	2.6
4/31/72	1.3	1.9	1.1
5/11/72	1.2	1.8	1.0
5/31/72	0.9	1.5	2.6
6/02/72	1.0	1.8	1.8
6/28/72	0.8	1.5	1.2
7/20/72	0.9	1.7	2.0
8/07/72	1.1	1.7	2.0
8/23/72	1.0	1.4	1.6
9/20/72	1.8	2.1	3.5
10/04/72	1.3	1.7	1.3
11/16/72	1.4	1.6	2.2
12/20/72	1.3	1.4	2.0
1/04/73	NM	NM	NM
2/23/73	1.8	2.6	2.0
3/26/73	1.7	1.7	1.2
Mean	1.6	1.9	2.1
Std. Dev.	0.7	0.4	0.8

[a] Pigment analysis using the techniques of Lorenzen (28) for "*in vivo*" fluoroescence of chlorophyll *a*.

NM = Not Measured

Table 46. Species diversity indices of composite plankton samples (surface and bottom water) taken from the limnetic zone in each of the three test ponds.

Date	Species Diversity Indices[a,b]		
	Drained Engine Pond	Drained Engine Pond	Control Pond
6/28/71	1.04	0.70	1.20
7/05/71	1.96	1.49	1.85
7/28/71	1.77	1.84	1.83
8/03/71	1.40	1.26	1.80
8/17/71	2.04	1.82	1.50
8/27/71	0.81	0.40	1.06
9/15/71	1.70	0.54	1.41
9/21/71	1.06	0.68	0.81
10/18/71	0.22	0.38	1.12
11/24/71	1.71	1.87	1.32
12/02/71	1.83	1.79	0.29
12/15/71	0.80	1.10	1.43
1/31/72	1.02	0.65	0.40
2/10/72	0.90	0.35	0.24
3/02/72	1.83	1.66	1.29
3/22/72	1.39	0.76	1.63
4/04/72	1.59	2.04	1.27
4/20/72	1.65	2.07	1.51
May	NM	NM	NM
6/22/72	1.62	1.30	1.84
7/28/72	1.82	0.53	1.41
8/07/72	2.40	1.97	1.14
8/17/72	2.18	1.80	1.77
8/24/72	2.02	1.20	1.88
September	NM	NM	NM
October	NM	NM	NM
11/10/72	2.01	2.09	1.45
11/16/72	2.32	1.74	1.84
12/14/72	1.07	1.57	0.11
12/19/72	1.65	0.66	1.82
12/29/72	1.25	1.30	1.12
1/04/73	0.64	0.82	0.52
1/15/73	1.11	1.88	1.78
1/22/73	1.18	1.22	1.81
2/02/73	0.94	0.28	0.77
2/19/73	1.07	0.44	1.22
2/26/73	0.08	1.51	1.90
3/02/73	0.27	1.19	2.24
3/09/73	0.90	1.30	1.94
3/16/73	0.78	0.76	2.00
3/26/73	0.13	0.46	3.06
4/02/73	0.54	0.97	2.25

[a] Shannon-Weaver diversity index to base e

[b] NM - Not Measured

Table 47. Comparisons of phytoplankton species diversity between ponds using one-way ANOVA and 95 percent confidence level.

Null Hypothesis (Ho)	Time Interval	Significance
Ho: All ponds equal	6/28/71 to 9/21/71	N.S., accept Ho
Ho: All ponds equal	10/18/71 to 11/16/71	N.S., accept Ho
Ho: All ponds equal	12/04/72 to 4/02/73	0.01, reject Ho: Control > treated ponds

1973 at which time maximum treatment levels occurred. Control Pond's species diversity increased significantly above the treated ponds. Mean values recorded during this period were: Drainless Engine Pond, 0.75; Drained Engine Pond, 1.02; Control Pond, 1.61.

Phytoplankton species diversity indices from other Florida lakes were not available for seasonal comparisons. However, in light of the oligotrophic chemical nature of the test ponds, species diversity indices were low as mean values ranged from 1.01 to 1.40. Low species diversity indices were primarily influenced by "blooms" of one organism, Anacystis marina. This taxon was responsible for significant differences in both species diversity indices and cell counts in the Drainless Engine Pond and the Drained Engine Pond during 1973.

Results of a linear regression analysis comparing species diversity indices to treatment levels in the treated ponds found low correlation (correlation coefficients of -0.10 and -0.46). This suggests that the difference observed between the control and the treated ponds was affected by factors other than engine emissions.

Phytoplankton Primary Productivity

In studying the annual trends of the three test ponds it is noted that phytoplankton productivity in the limnetic zone of the Control Pond ranged from less than 0.01 g Cm^{-3} day^{-1} to a high of 1.1 g Cm^{-3} day^{-1} (Figure 10). With exception of the last sample (March, 1973) the treated ponds exhibited a narrower range of < 0.01 to 0.5 g Cm^{-3} day^{-1}. Average productivities in the baseline study were 0.2 g Cm^{-3} day^{-1} in the Control Pond and 0.1 g Cm^{-3} day^{-1} in each of the treated ponds. A pooled sample t-test indicated that the difference was significant. During treatment, production averaged 0.6 g Cm^{-3}

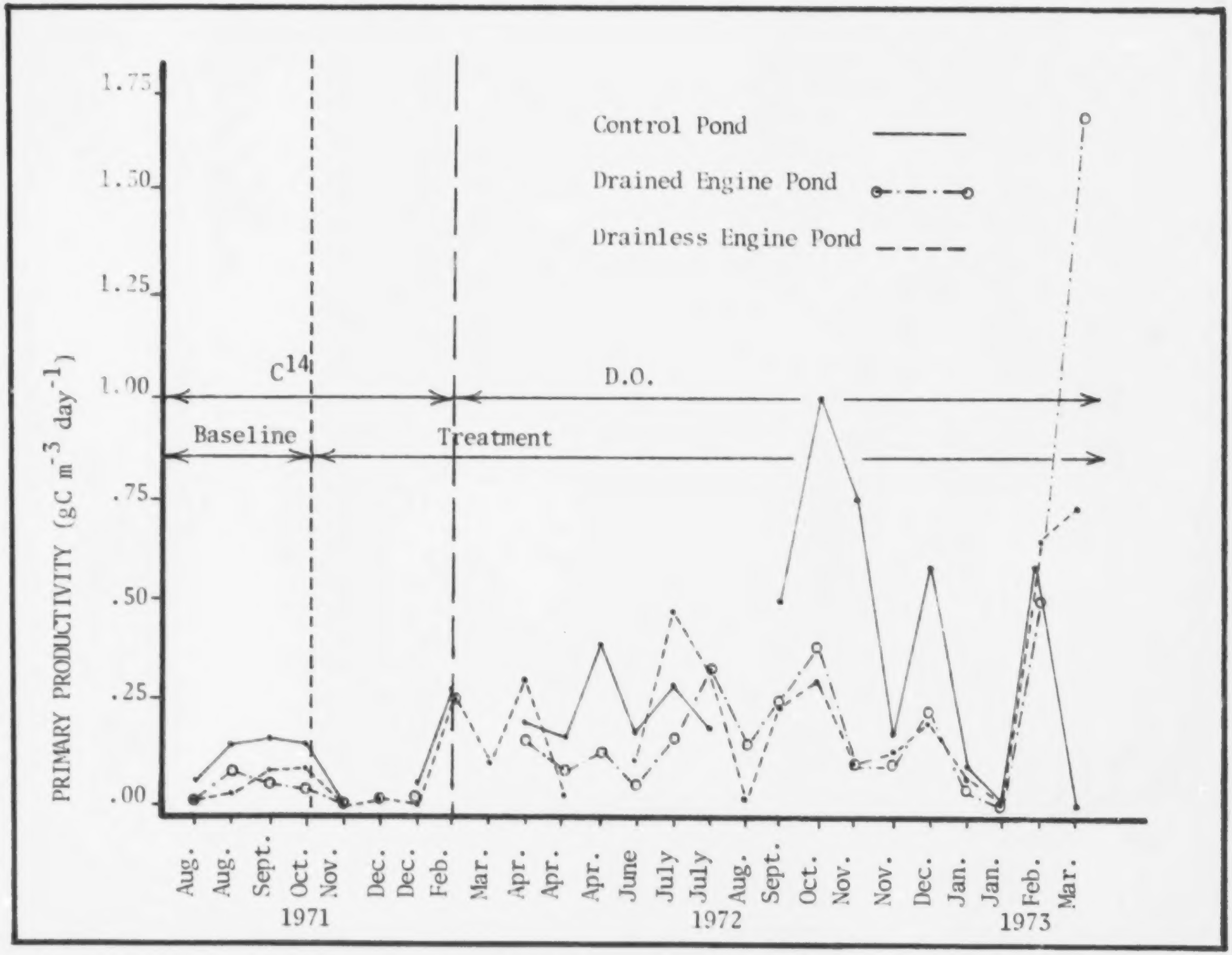

Figure 10. Phytoplankton primary productivity (g C m^{-3} day^{-1}) in the surface of the limnetic zone.

day^{-1} in the Control Pond and 0.2 g Cm^{-3} day^{-1} in each of the treated ponds. The same t-tests were applied, which indicated significant treatment differences. Since the same differences were observed before treatment as during treatment, a two-way ANOVA test of the effect of treatments and months on phytoplankton primary productivity was employed. It was assumed that there was no yearly effect and that data collected in 1973 was a replicate of that collected in 1972 during corresponding months of the year.

Appendix F (Table F13) summarizes mean phytoplankton productivity for each month and treatment. The productivity for the months varied significantly in all three ponds. For both the Drained Engine and Drainless Engine Ponds, the productivity was the highest in the months of February and March, while the Control Pond had the highest productivity in October and December. The lowest productivity took place in January in all three ponds.

Table F14 (Appendix F) summarizes a two-way analysis of variance in which the joint effects of month and treatment are considered. It is indicated therein that a significant interaction between treatment and month exists which implies that differences among the treatments change from month to month. This being the case, it was necessary to compare treatments for each different month of interest (Table F15). Significant differences at the 99 percent confidence level in average phytoplankton productivity among the three ponds occurred in the months of March and October. During March, a rank ordering of the ponds from highest to lowest productivity (in units of g Cm^{-3} day^{-1}) was Drained Engine Pond (1.73), Drainless Engine Pond (0.58), and Control Pond (0.01). During October a similar ordering would be Control Pond (1.01), Drained Engine Pond (0.38), and Drainless Engine Pond (0.30).

Not too much physical significance can be attached to these differences and to the interaction effect, however, since by chance measurements may be taken on days when blooms (photosynthetic pulses) are present. For example, the high productivity in the Drainless Engine Pond in March, 1973 may be associated with the bloom of one algal species (Anacystis marina), and the effect of such a large datum may be enough to cause significant interactions. Therefore, little conclusive evidence is available to explain how the treatments affect phytoplankton productivity.

A factor to consider during the summer is the availability of carbon dioxide and its relationship with phytoplankton production. This is primarily of concern in the grassbed community which is inhabited by macrophytes, periphyton and to a lesser importance by phytoplankton. Together these primary producers are capable of depleting the supply of carbon dioxide. In the limnetic zone, however, phytoplankton are the only major users of carbon dioxide. As a result, carbon dioxide is much less likely to become limiting in the limnetic zone and therefore affect phytoplankton productivity. Although it is conceivable that carbon dioxide from outboard engine emissions could stimulate phytoplankton growth during carbon dioxide limiting conditions, no evidence of this was noted in this study.

A bioassay experiment was performed in the Drainless Engine Pond during 1971 in which high concentrations of outboard emissions (at least 132 times testing levels in 1971) were shown to reduce phytoplankton productivities (Table 48). A stimulatory effect was observed at a ratio of 1:250 (ratio of exhaust water to pond water). However, at higher ratios of exhaust water to pond water, productivities were inhibited. These results are similar to those reported by Ferris (13) in which outboard fuel emissions significantly reduced phytoplankton productivity in oil spiked water. Although there was an obvious impact, it is unrealistic to consider that motorboating could ever reach these levels, even in a marina.

Table 48. Effects of high levels of engine emissions on phytoplankton productivity in the Drainless Engine Pond reported as CPM of radioactive carbon assimilated, November 30, 1971.

Treatment[a]	Productivity (CPM)	
	Surface	Bottom
Control (0:250)	407	670
1:250	462	247
10:240	54	54
100:150	42	41
250:0	36	0

7 = 76.77 + 0.60

CORRELATION COEFFICIENT = 0.78

[a] A drainless 9.8 hp Mercury motor was operated at 1000 rpm in a 50 gallon drum containing 37 gallons of pond water until 0.5 gallons of indoline was burned. Pond water collected from the Drainless Test Pond was then inoculated with the "exhaust water" and the effects on the phytoplankton productivity were measured.

SUMMARY

1. No effects of overt toxicity or stimulation were observed within the plankton community in the limnetic zone as a result of the treatment effects of outboard motor emissions.

2. Temporal changes were observed in species composition, standing crop, species diversity, chlorophyll a levels and primary production. These changes were primarily due to seasonal variations in nutrient levels, temperature, and light levels and were not associated with the treatment effects of outboard motor emmissions.

3. Phytoplankton biomass as measured by chlorophyll a was low (1-3.5 mg/m^3) in all ponds during the year. These data compare favorably with similar acid-soft water lakes in Florida and thus should not be associated with an inhibitory effect caused by outboard motor emissions.

4. No definitive evidence was obtained from phytoplankton primary productivity studies as differences between the three ponds were difficult to delineate because of the high level of natural variability.

5. Phytoplankton bioassays conducted on a limited basis show outboard motor exhaust water at concentrations of greater than 4 ppm to inhibit photosynthesis. Similar results have been noted by Kumar (41) using raw fuel mixed with lake water. This threshold concentration represents a level of stressing approximately 130 times the present rate in the treated ponds. It is unrealistic to think that boat usage would reach this level on any recreational lake.

SECTION VIII

BENTHIC MACROINVERTEBRATES

Benthic organisms exhibit certain qualities that make their use in aquatic studies particularly important. Among these are their relatively long life cycles, constant presence due to their sedentary habits, and differing tolerances to stress (22). Some species of invertebrates, as with other groups of organisms, cannot tolerate any appreciable water quality change, whereas others are tolerant and are able to live and multiply under adverse conditions. Usually, though, it is not realistic to isolate a parttticular group, genus or even species of invertebrates to indicate the presence or absence of biotic stresses. Nevertheless, close monitoring of certain taxonomic groups such as tubificids (a tolerant group), chironomids (a tolerant group), and mayflies (a sensitive group) can be informative as too the degree of biotic stress.

In the present study benthic macroinvertebrates were sampled on a regular basis to determine the effects due to engine treatment. The invertebrates were analyzed and identified with certain questions related to their community structure, distribution, and diversity.

FIELD AND LABORATORY PROCEDURES

Benthic samples were collected with an Ekman dredge beginning in August, 1971 and continuing through March, 1973. Samples were collected on a quarterly basis until February, 1972, and then on a monthly basis for the remainder of the study. Five stations in the Drained Engine Pond, five stations in the Control Pond, and four stations in the Drainless Engine Pond were collected as composites of three grabs through October, 1972, at which time the sampling procedure was changed to duplicate samples at each station. The locations of the stations are shown in Figure 11. This sampling technique was chosen to focus on the effect of outboard motor operation on bottom dwelling organisms. Surface dwellers such as the aquatic hemipterans have largely been ignored in this study.

In the field, each of the samples was strained using a U.S. Standard No. 30 sieve, stained with rose Bengal, and preserved in a 10 percent formalin solution. In the laboratory, the samples were rinsed again in a No. 30 sieve and the organisms were manually separated from detritus and other matter retained by the sieve. Species identifications were determined using standard taxonomic references whenever applicable. Major taxonomic references included Mason (29), Ward and Whipple (55), Parrish (34), Pennak (35), Johannsen (18, 19,20,21) and Usinger (52). Diversity indices were calculated for each sample by using the Shannon-Weaver formula.

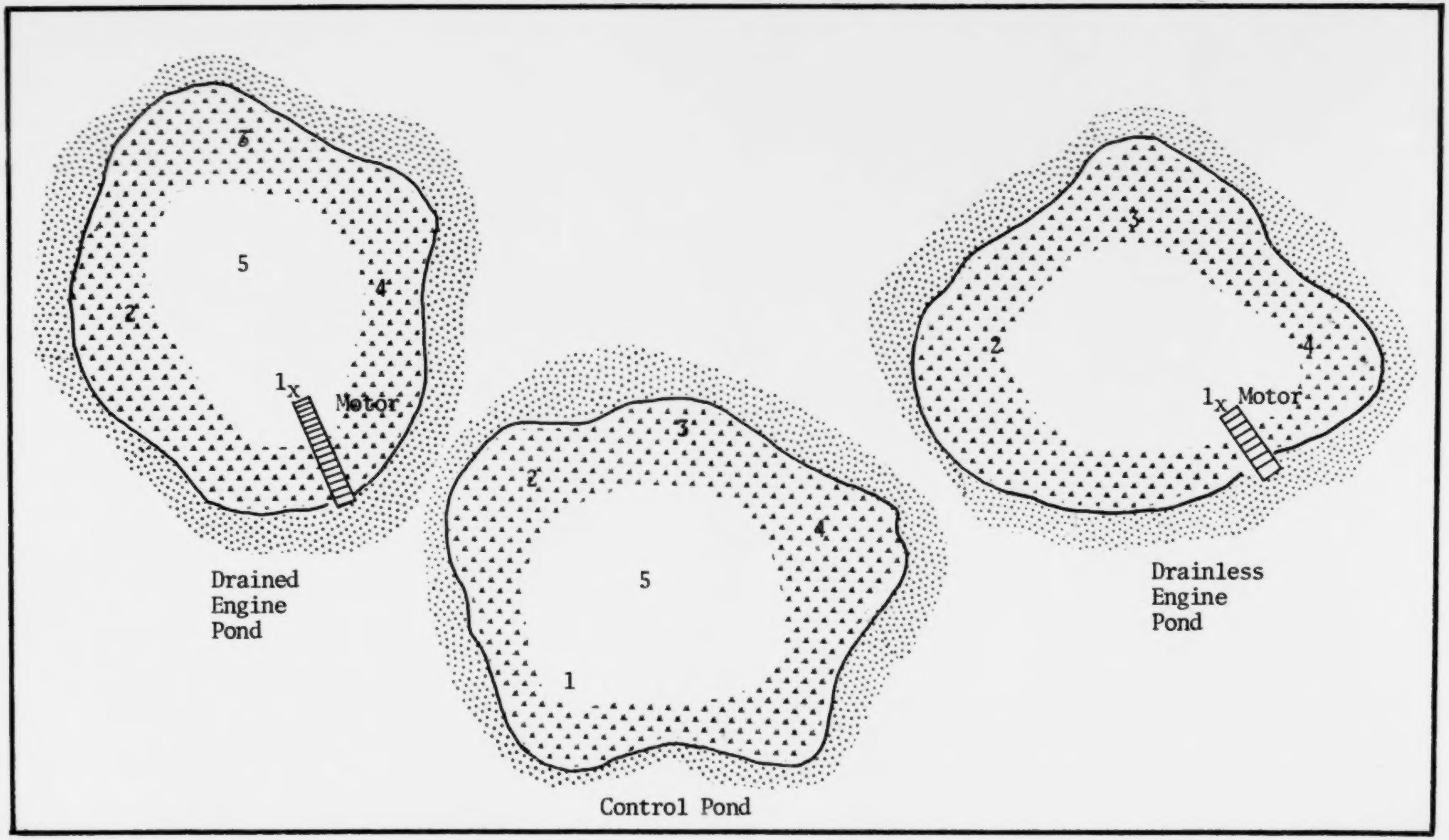
3
5
4
2
1x
Motor
Drained
Engine
Pond
3
2
4
5
1
Control Pond
3
2
4
1x
Motor
Drainless
Engine
Pond

Figure 11. Benthic sampling locations of the test ponds.

RESULTS AND DISCUSSION

A list of the macroinvertebrates collected in the three ponds is given in Appendix E. As shown by the data, the benthos in the three ponds were dominated by insect larvae, primarily the dipterans. The most abundant dipteran family was Chironomidae which comprised between 8 and 94 percent of the total number of invertebrates collected from each pond (Table 49). Pooled sample t-test showed no significant difference in the abundance of chironomids among the three ponds (Table 50).

Table 49. Relative abundance of chironomids collected in the ponds from August, 1971 through March, 1973.

	Relative Abundance		
Date	Drained Engine	Drainless Engine	Control
8/18/71	34	28	36
10/19/71	8	25	32
2/07/72	49	86	35
3/08/72	30	51	31
4/03/72	30	94	23
5/11/72	43	50	35
6/26/72	38	48	27
8/03/72	29	59	47
9/14/72	52	40	42
10/13/72	39	35	74
12/27/72	65	59	62
1/31/73	59	74	70
2/21/73	55	66	72
3/21/73	71	88	72

Relative abundances are reported as percent of the total invertebrates collected.

Procladius was found to be the dominant chironomid in the ponds and remained so throughout the study, except in the Drainless Engine Pond during August, 1972, October, 1972, and January, 1973, when the dominant chironomids were *Clinotanypus*, *Chironomus* (*Dicrotendipes*) and *Chironomus* (*Chironomus*). *Procladius* did not increase significantly in any pond throughout the study. The density of various *Chironomus* species appears to have increased in the Drainless Engine Pond, and in the Control Pond but not in the Drained Engine Pond. Both *Chironomus* and *Procladius* are considered to be tolerant of organic enrichment (7).

Table 50. Comparisons of average densities, diversities and relative abundances of macroinvertebrates between ponds and stations using pooled t-tests at the 95 percent and 99 percent levels of confidence

Null Hypothesis (Ho)	Level of Confidence	Parameter	Time Interval	Significance
Ho: Drained Engine Pond = Control Pond	95%	Chironomid Relative Abundance	August 1971 - March 1973	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	95%	Chironomid Relative Abundance	August 1971 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Drainless Engine Pond	95%	Chironomid Relative Abundance	August 1971 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	99%	Diversity Indices	March 1972 - March 1973	Sig., reject Ho
Ho: Drainless Engine Pond = Control Pond	95%	Diversity Indices	March 1972 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Drainless Engine Pond	95%	Diversity Indices	March 1972 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	95%	Sta. 1 Diversities (DW)[a]	March 1972 - March 1973	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	95%	Sta. 1 Diversities (DW)	March 1972 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Drainless Engine Pond	95%	Sta. 1 Diversities (DW)	March 1972 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	95%	Sta. 3 Diversities (SW)[b]	March 1972 - March 1973	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	95%	Sta. 3 Diversities (SW)	March 1972 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Drainless Engine Pond	95%	Sta. 3 Diversities (SW)	March 1972 - March 1973	N.S., accept Ho
Ho: Drained Pond Sta. 1 = Drained Pond Sta. 3	95%	Diversity Indices SW vs. DW[c]	March 1972 - March 1973	N.S., accept Ho
Ho: Drainless Pond Sta. 1 = Drainless Pond Sta. 3	95%	Diversity Indices SW vs. DW	March 1972 - March 1973	N.S., accept Ho
Ho: Control Pond Sta. 1 = Control Pond Sta. 3	95%	Diversity Indices SW vs. DW	March 1972 - March 1973	N.S., accept Ho
Ho: Drained Engine Pond = Control Pond	95%	Tubificid Relative Abundance	August 1971 - March 1973	N.S., accept Ho
Ho: Drainless Engine Pond = Control Pond	95%	Tubificid Relative Abundance	August 1971 - March 1973	Sig., reject Ho
Ho: Drained Engine Pond = Drainless Engine Pond	95%	Tubificid Relative Abundance	August 1971 - March 1973	Sig., reject Ho

[a] Limnetic Zone Station (DW)
[b] Littoral Zone Station (SW)
[c] Littoral Zone Station vs. Limnetic Zone Station

Chironomid densities were compared with plankton productivities, grassbed productivities, and standing crops of plankton. Although there was no correlation between plankton productivity, grassbed productivity and chironomid densities, there does appear to be a positive correlation between chironomid density and plankton standing crop.

The second most abundant dipteran family, Chaoboridae, was also dominant in the three ponds. *Chaoborus punctipennis* was the most frequently encountered plankton midge larvae. Other dipterans observed were the horsefly larvae (*Chrysops*) and the midges (*Bezzia*, *Palpomyia*, and *Dasyhelia*). In all the cases, there were no overt differences between the populations of the three ponds.

Tubificids ranked next in abundance as their relative abundance (Table 51) averaged 6 to 13 percent of the total counts. The highest frequency of occurrence was observed in the Drainless Engine Pond. Similar frequencies of tubificids were found in the Drained Engine Pond (6 percent) and the Control Pond (7.5 percent). Prior to treatment, the same ranking order was observed in the three ponds. Statistical tests supported these findings as no significance was obtained except for the highest frequency of occurrence (of tubificids) in the Drainless Engine Pond.

Table 51. Relative abundance of tubificids collected from the ponds from August, 1971 through, 1973.

	Relative Abundance		
Date	Drained Engine	Drainless Engine	Control
8/18/71	4	12	6
10/19/71	2	39	7
2/07/72	4	5	11
3/08/72	10	14	0
4/03/72	6	0	12
5/11/72	0	21	16
6/26/72	4	9	14
8/03/72	10	14	4
9/14/72	8	26	8
10/13/72	17	36	6
12/27/72	8	6	5
1/31/73	1	0	2
2/21/73	10	0	9
3/21/73	2	1	5

Relative abundances are reported as percent of the total invertebrates collected.

Amphipods and odonates were also present in significant numbers while other groups comprised smaller percentages of the total benthic fauna. Less abundant groups included the mayflies, roundworms, caddisfly larvae, flatworms, leeches, beetle larvae, water fleas and water mites.

The caddisfly larvae dominated by Oecetis and Polycentropus, showed no decrease in abundance during the study. These two genera are considered to be sensitive organisms (6). On the other hand, several families of Odonata may have become more prevalent in each pond during the course of the study. These included Coenagrionidae, Lestidae and Libellulidae. The burrowing odonates, Gomphidae, were rarely collected in the three ponds.

Of particular interest was the absence of three mayfly taxa (Baetidae, Ephemerellidae, Tricorythidae) from the treated ponds and their presence in the Control Pond. Mayfly species belonging to these three families are non-burrowing bottom inhabitants of the littoral zone and are usually associated with aquatic vegetation and detritus. The highly stress-tolerant mayfly Caenis was, however, present in all three ponds.

A check list of the families of benthic macroinvertebrates noted in the three ponds is presented in Table 52.

Densities

Figure 12 shows that the monthly density patterns of the treated ponds closely resemble the control. From the data a definite seasonal pattern is apparent. In all three ponds the period of lowest density was in the late spring and early summer of 1972. During late spring many species of insects emerged and biomass and numbers fell steeply. Generally, this decline was followed by an increase due to the hatching of summer species.

Normally, in insect-dominated bodies of water, there is a tendency for numbers to decrease in late summer because the hatching of eggs declines and the fall emergence of later flying insects begins. However, this pattern did not occur in the ponds, possibly because the ponds are dominated by chironomids which may not fit this trend since they are comprised of many summer species (17). In addition, the loss by emergence may also have been offset by recruitment due to hatching of eggs from species that overwinter.

Usually the fall is a period of hatching for species which will develop during the winter, and for the growth of permanent species born during the summer. Consequently, this period is one of increasing, often maximum numbers, and of increasing biomass, despite losses by late flying species of insects. Losses caused by predation

Table 52. A checklist of families denoted for the three ponds.

Taxa[a]	Drainless Engine Pond	Drained Engine Pond	Control Pond
Nematoda		X	
Oligochaeta	X	X	X
Glossiphoniidae		X	X
Pisciolidae	X	X	X
Talitridae	X	X	X
Hydracarina	X	X	
Baetidae			X
Ephemerellidae			X
Gomphidae	X	X	X
Libellulidae	X	X	X
Leptoceridae	X	X	X
Chaoboridae	X	X	X
Chironomidae	X	X	X
Ceratopogonidae	X	X	X
Caenidae	X	X	X
Tricorythidae			X
Coenagrionidae		X	X
Lestidae	X	X	X
Psychomyiidae	X	X	
Tabanidae	X	X	X
Pyralididae		X	X
Turbellaria	X		
Hydrophilidae		X	X
Total	15	19	19

[a] Presence of a particular taxon denoted by X.

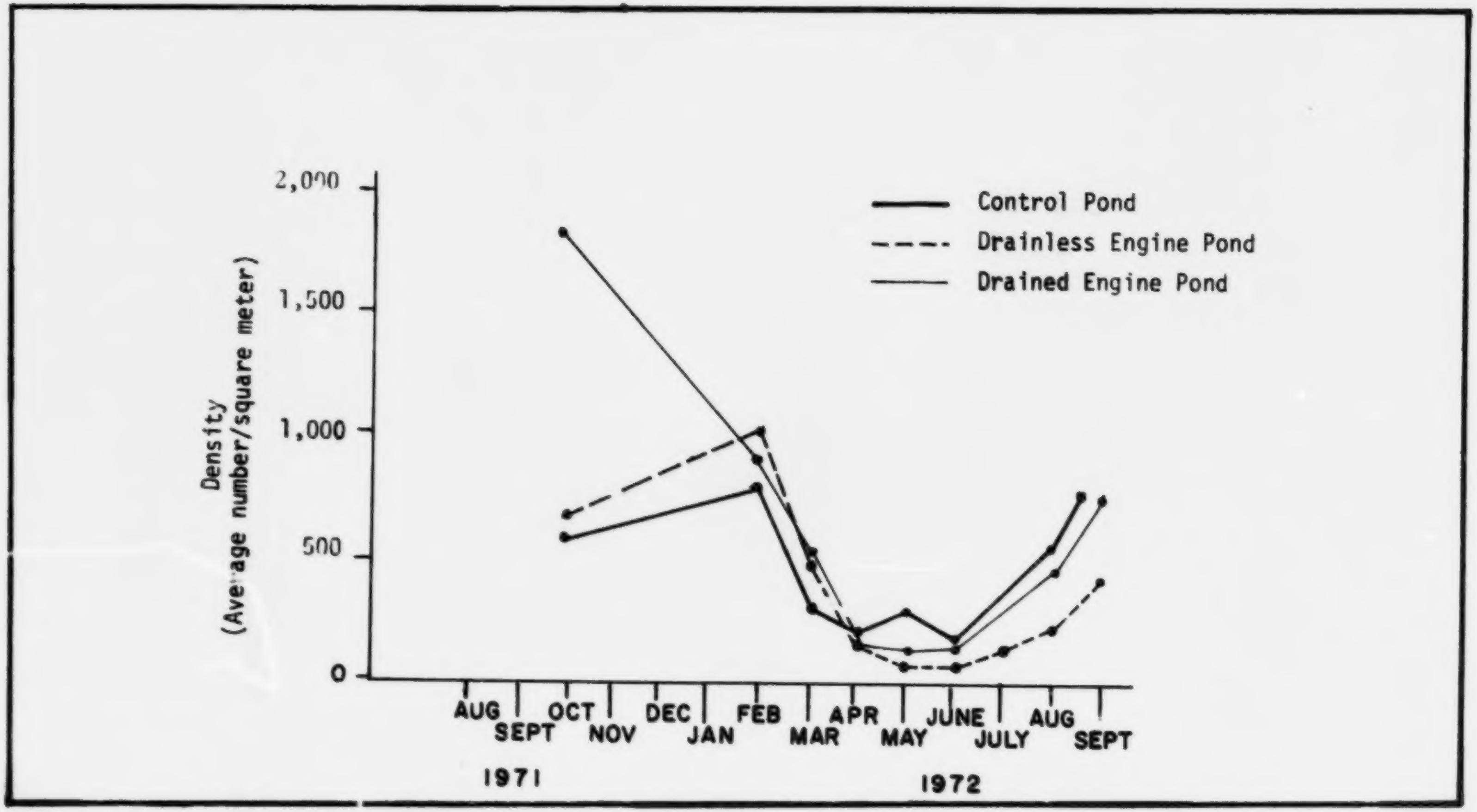

Figure 12. An annual cycle of total macroinvertebrate densities determined for the three test ponds during treatment.

and other factor in the environment tend to be made up by the continued hatching of eggs (17). The period of increasing density was observed in all three ponds during September, 1972.

A reduction in numbers was observed through the winter of 1971-1972. During the winter, growth of many animals decreased, and the rate of recruitment from newly hatched eggs followed the same trend. As a result, numbers tended to decline as individuals died or were consumed by predators. However, biomass may have increased as growth of surviving individuals offsets losses.

Only the annual cycle of total density presented in Figure 12 has been reported and discussed herein. Data collected later in the study are not comparable since a different level of replication was employed during sampling.

Diversity Indices of Benthic Macroinvertebrates

Species diversity indices of the benthos are reported herein beginning in April, 1972 since prior to that date, chironomids were not identified to species. Additional approximations of diversity indices have been computed by treating all chironomids collected as one species. As expected, the diversity indices averaged approximately 25 percent lower when the chironomids were grouped as one species (Figures 13 and 14). Generally higher diversities were observed in the Control than the treated ponds. When grouping the chironomids together as one species, no difference was evident between the two treated ponds. However, the Drained Engine Pond exhibited a lower diversity when the chironomid species were treated independently.

The mean diversity indices (chironomids identified to species) of the Drained Engine, Drainless Engine, and the Control Pond were 1.68, 1.89 and 2.11, respectively. Using pooled sample t-tests, the Drained Engine Pond had significantly lower diversity indices than the Control at the 95 and the 99 percent level of confidence. However, no significant differences in diversity were found between the Drainless Engine Pond and the Control Pond, or between the Drainless Engine Pond and the Drained Engine Pond.

Comparisons of diversity indices (chironomids identified to species) computed for Station No. 1 (deepwater, 2-3 meters and adjacent to motors) and Station No. 3 (shallow water, 1-2 meters and adjacent to grassbed) during the period of March, 1972 through March, 1973 indicated no significance at the 95 percent level of confidence using a t-test. Mean diversity indices at Station No. for this period were 1.06, 1.12 and 1.43 for the Drained Engine, Drainless Engine and Control Ponds, respectively (Table 53). The lower diversity indices observed in the treated ponds may represent a response to engine treatment. Station No. 1 is located directly beneath the motors in the treated ponds and shows slight depressions due to engine scouring. The shallow water diversity indices (Station No. 3, 1-2 meters) in the Drained Engine, Drainless Engine and Control Ponds were similar as respective values of 1.30, 1.36, and 1.46 were obtained. Comparisons were then made between the shallow and deep zones within ponds. The differences between the mean values of Stations No. 1 and No. 3 in the Control Pond (.03) are less than the differences in Drained Engine Pond (.26) or Drainless Engine Pond (.24), although pooled sample t-tests indicated that there was no significance at the 95 percent level of confidence.

Table 53. A comparision of littoral zone (Station 3) diversities to limmetic zone (Station 1) diversities from August, 1971 through March, 1973.[a,b]

	Diversity Indices					
Date	Drained Engine		Drainless Engine		Control	
	Sta. 1	Sta. 3	Sta. 1	Sta. 3	Sta. 1	Sta. 3
8/18/71	0.76	0.84	0.85	1.14	1.37	1.21
10/19/71	0.32	1.30	0.89	1.56	1.43	1.38
2/07/72	0.58	0.92	1.18	0.37	0.75	1.03
3/08/72	0.73	1.46	1.12	1.62	1.89	1.51
4/03/72	0.50	1.36	0.45	1.68	2.43	0.36
5/11/72	1.47	0.00	1.10	1.15	2.23	1.61
6/26/72	0.00	1.28	0.69	1.56	1.49	1.28
8/03/72	1.71	1.17	2.08	1.85	1.28	2.04
9/14/72	1.13	1.04	1.29	1.26	1.58	1.75
10/13/72	1.89	1.61	0.93	1.69	1.21	1.00
12/27/72	1.49	1.47	1.62	1.58	0.70	1.00
1/31/73	1.06	1.30	0.21	0.88	0.65	2.45
2/21/73	0.42	1.36	1.83	1.63	1.77	1.78
3/21/73	1.66	1.79	1.46	1.04	1.12	2.01
Mean Values	1.06	1.30	1.12	1.36	1.43	1.46

[a] Diversities calculated with chironomids pooled as one species.
[b] Shannon-Weaver formula (Base e)

Supplemental statistical analysis were performed to determine the joint effects of treatments and months on diversity (chironomids identified to species). These results are presented in Appendix F, Tables F16 and F19.

Tables F16 and F17 give the mean macroinvertebrate diversity indices for each treatment and each month or season, respectively. Note that May and June had the highest indices and February and December had the lowest indices.

During the period of greatest stressing as a result of low water (December, 1972 - March, 1973), there was no significant decrease in diversity. In fact, diversities of the Drained Engine Pond steadily increased from a low in November, 1972 to its maximum value of 2.11 in February and March of 1973. The diversity in the Drainless Engine Pond and the Control Pond fluctuated during this period.

Tables F18 and F19 summarize the two-way analyses of variance in which months or seasons, respectively, are used to represent temporal effects. In both cases no interaction of these temporal variables with treatments was found. In addition, no overall significant differences were found in diversity indices for the different months (or seasons).

Since the temporal effects are small, the analysis by pooled sample t-tests is justified. In particular, the Drained Engine Pond had significantly lower average diversity indices than the Control Pond.

Although the benthic macroinvertebrates of the Control Pond were the most diverse, there were no clear-cut effects of engine stressing on the diversity of the treated ponds. A point which should be recognized in attempting to define the effects of engine treatment on diversity, is that the index values probably will not be linearly proportional to the degree of stressing. Instead, diversities may cycle up and down several times before declining as the change in the environment progresses (1). As evidenced in the data, diversity indices did not show a declining trend in the two treated ponds nor did the frequency of their cyclic patterns increase in the treated ponds.

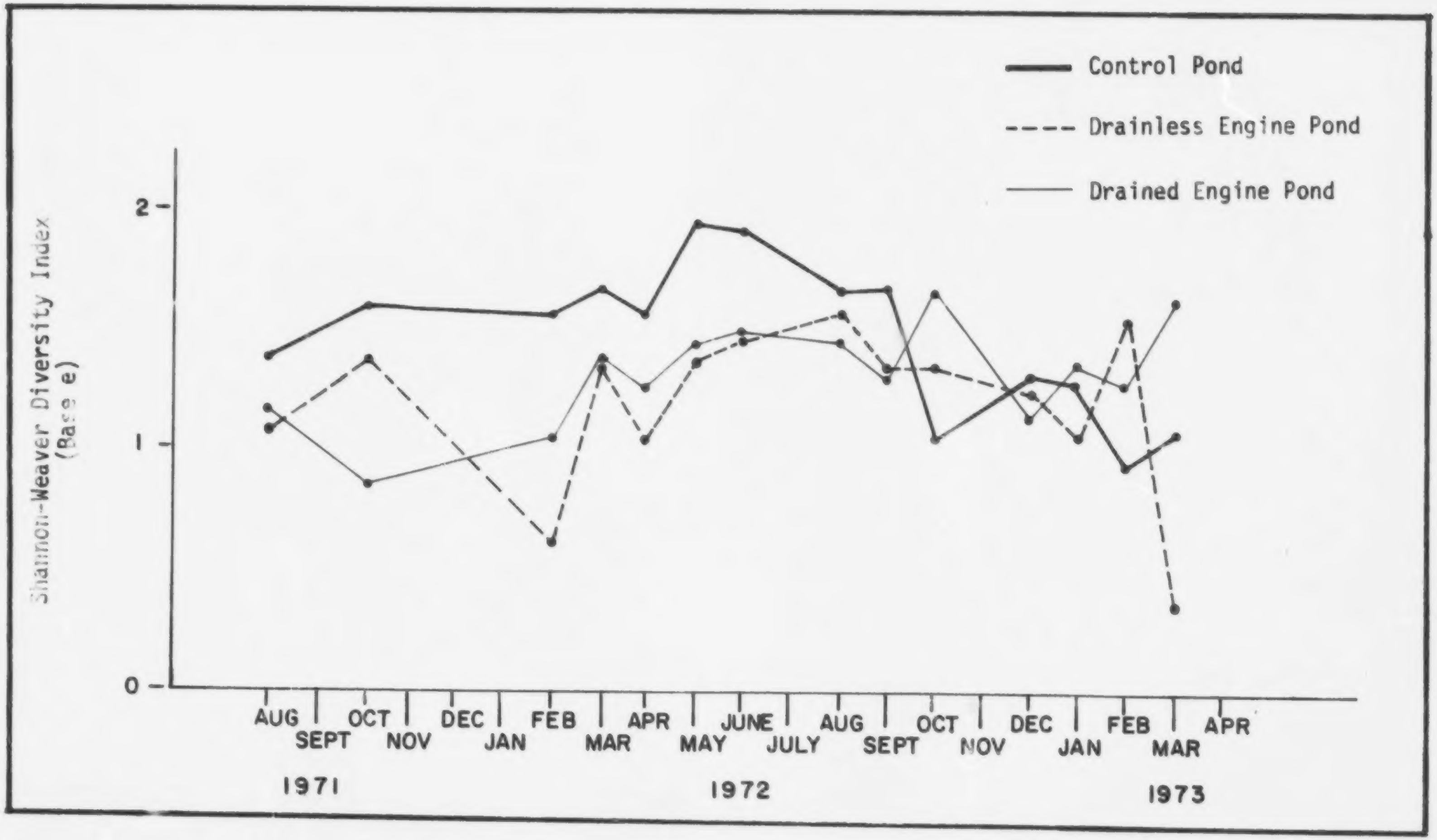

Figure 13. Diversity indices of the benthos with the chironomids pooled together as one species.

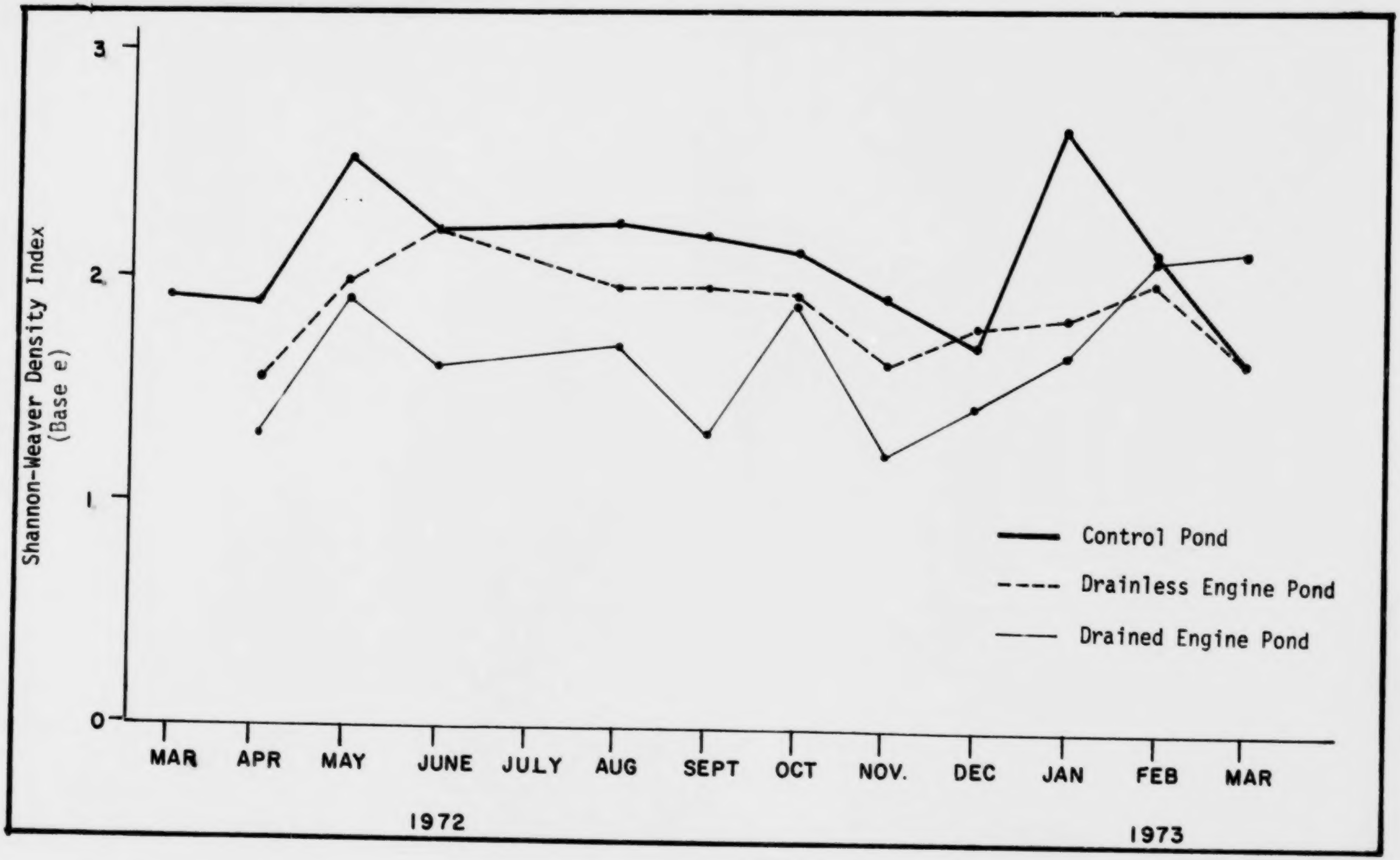

Figure 14. Diversity indices of the benthos with the chironomids identified to the species level.

SUMMARY

1. Monitoring of "pollution tolerant" indicator macroinvertebrates suggested no effects due to engine operation as increases in the density of these organisms were rare and only occurred when similar increases occurred in the Control Pond. The organisms monitored were a pollution tolerant mayfly, Caenis, the tolerant chironomids *Chironomus* and *Procladius*, and crawling or burrowing Oligochaetes. In contrast, three sensitive mayfly taxa (Baetidae, Ephemerellidae, Tricorythidae) were present in the Control Pond but not in the two treated ponds.

2. Engine treatment did not appear to affect the diversity in either the Drainless Engine Pond or the Drained Engine Pond, although diversity indices were lower in the two treated ponds than in the Control Pond. A small area on the bottom immediately underneath the motors may have been affected since the constant turbulence caused by motor operation scoured the bottom.

3. Density patterns were similar in all three ponds and do not appear to be affected by engine treatment.

4. The fauna in the treated ponds appear to be similar to that found in other oligotrophic Florida lakes.

5. Based on the monitoring of the composition of the benthic community, total pond diversities, diversities of selected stations, total pond densities, densities of selected stations, and densities of selected indicator organisms and groups of macroinvertebrates, engine treatment did not significantly affect the benthic macroinvertebrates.

SECTION IX

SENSORY PANEL TESTS FOR FISH TAINTING

The objective of this study was to determine if any differences in taste existed among the fish from Control, Drained Engine, and Drainless Engine Ponds. Samples of sunfish (Lepomis sp.) and large-mouth bass (Micropterus salmoides) were collected and tested by a panel of eleven judges at the University of Florida Food Sciences Laboratories. Taste tests were conducted beginning in September, 1971, and continued through August, 1972. A triangular testing method was employed in which the judges were given three samples, two of which were identical. They were then asked to identify like samples. Judges were also asked to rate the samples on a scale from 1 (very bad taste) to 7 (very good taste) and to comment on whether or not any traces of "tainting" by petroleum products could be detected.

METHODS

The fish tested were obtained by angling on the day prior to testing. The fish of each sample were eviscerated, washed, and cooked to an internal temperature of 180°F for 30 minutes. Edible muscle tissue was separated from each individual fish, and combined with the edible tissue of other fish of the same sample. Each genera (e.g. sunfish or bass) was then thoroughly mixed together and given a code number. Three separately coded portions, two of which were of the same sample and genera but coded differently were presented to each panel member. Panel members were then asked to determine if any differences existed among the three coded samples and if so to identify duplicate samples. In the test conducted during November, 1971, and August, 1972, the panel was asked to rate the taste of the samples by using the following scale (Table 54).

Table 54. Taste scale used by members of the test panel from the University of Florida Food Sciences Laboratory.

Interpretation	Taste Unit
Like Very Much	7
Like Moderately	6
Like Slightly	5
Neither Like nor Dislike	4

Table 54. Continued

Interpretation	Taste Unit
Dislike Slightly	3
Dislike Moderately	2
Dislike Very Much	1

RESULTS AND DISCUSSION

Results of the sensory panel are presented in Tables 55, 56, and 57, along with identification of the samples which were tested. The taste of bass and sunfish was found to range from 4 to 6 in each of the three ponds.

Table 55 indicates that the judging panel could detect and correctly identify a taste difference among samples less than 50% of the time. Of the 98 decisions made by the panel during 1971, 41 decisions were correct.

Table 56 shows that in 1971 the sunfish from Control Pond were rated slightly lower than the sunfish from the test ponds. However, the difference between the mean scores is less than 0.5 taste units, which is hardly significant. The bass from Control Pond, on the other hand, were rated slightly higher than the bass from the treated ponds. Here again the range is very small, 0.6 units on the taste scale.

In 1972, as indicated by the data in Table 57, the sunfish from Control Pond tasted better than those from the treated ponds, but the bass of Control Pond were rated lower than those of the two treated ponds. In both cases the difference between the mean taste ratios is less than 1.0 taste unit.

The correlation between the number of judges indicating a taste difference among samples and the number correctly identifying the difference is low (42%). The subjectivity of the method, as well as little or no difference in the taste of the fish, is most likely responsible for the high level of incorrect decisions. In the four cases in which there is a high correlation between the number indicating a difference and the number correctly identifying a difference, it can be concluded that there probably is a difference in taste among the samples. However, no judge could describe any flavor present as "tainting" by petroleum products.

Table 55. Results of tests comparing the tastes of sunfish and bass between ponds during treatment in 1971.

Sample	Code	Date	Total Evaluations	Number Indicating a Difference	Number Indicating no Difference	Number Correctly Identifying a Difference	Number of Mistakes
Sunfish - Control vs. Drained & Drainless							
Sunfish Control	41	9/02/71	11	8	3	7[b]	1
Sunfish Control	26						
Sunfish Drainless & Drained	53						
Bass - Drained vs. Drainless							
Bass Drained	15	9/02/71	11	7	4	3	4
Bass Drained	22						
Bass Drainless	10						
Sunfish - Drained vs. Drainless							
Sunfish Drained	61	11/02/71	10	6	4	1	5
Sunfish Drainless	97						
Sunfish Drainless	50						
Bass - Control vs. Drained							
Bass Control	73	11/02/71	9	5	4	1	4
Bass Drained	39						
Bass Drained	14						
Bass - Control vs. Drainless							
Bass Control	53	11/02/71	10	9	1	8[b]	1
Bass Control	28						
Bass Drainless	88						
Bass - Drained vs. Drainless							
Bass Drained	59	11/02/71	9	7	2	6[b]	1
Bass Drainless	17						
Bass Drainless	3						
Sunfish - Drained vs. Drainless							
Sunfish Drained	87	11/10/71	10	8	2	3	5
Sunfish Drained	44						
Sunfish Drainless	67						
Bass - Control vs. Drainless							
Bass Control	20	11/10/71	10	9	1	6[b]	3
Bass Control	5						
Bass Drainless	41						
Sunfish - Control vs. Drained & Drainless							
Sunfish Control	94	11/30/71	9	4	5	2	2
Sunfish Drainless & Drained	66						
Sunfish Drainless & Drained	52						
Bass - Control vs. Drainless & Drained							
Bass Control	86	11/30/71	9	7	2	4	3
Bass Drainless & Drained	35						
Bass Drainless & Drained	18						
TOTAL			98	70	28	41[c]	29

[a] No. indicating no difference may or may not be a correct decision.

[b] High correlation between number indicating a difference and number correctly identifying the difference.

[c] Success ratio : $\frac{41}{98}$ = 42%

Table 56. Mean taste scores of sunfish and bass during November, 1971.

Sample	Date	Code	Fish Taste (mean)^{a}
Sunfish Control^{b}	11/30/71	94	4.9
Sunfish Drained Engine	11/10/71	87	5.0
Sunfish Drained Engine	11/10/71	44	5.3
Sunfish Drainless Engine	11/10/71	67	5.2
Sunfish Drainless & Drained Engine	11/30/71	66	5.0
Sunfish Drainless & Drained Engine	11/30/71	52	5.2
Bass Control^{c}	11/10/71	20	5.1
Bass Control	11/10/71	5	5.3
Bass Control	11/30/71	86	5.3
Bass Drainless Engine	11/10/71	41	4.7
Bass Drainless & Drained Engine	11/30/71	35	4.7
Bass Drainless & Drained Engine	11/30/71	18	5.0

[a] Scale: 1 (very bad taste) to 7 (very good taste).
[b] Sunfish (*Lepomis sp.*), primarily bluegills and redear sunfish.
[c] Largemouth Bass (*Micropterus salmoides*)

Table 57. Mean taste scores of sunfish and bass during the time period of February to August, 1972.

Date	Fish Taste^{a}					
	Drainless Engine Pond		Drained Engine Pond		Control Pond	
	Bass^{b}	Sunfish^{c}	Bass^{b}	Sunfish^{c}	Bass^{b}	Sunfish^{c}
2/29/72		4.8	5.4		4.9	5.0
4/02/72		4.7		4.9		5.4
6/01/72	5.6	4.9	5.4	5.1	5.5	4.7
7/05/72		5.3	5.5	5.3	5.3	5.5
8/31/72	5.7		5.8		5.6	

[a] Scale: 1 (very bad taste) to 7 (very good taste).
[b] Sunfish (*Lepomis sp.*), primarily bluegills and redear sunfish.
[c] Largemouth Bass (*Micropterus salmoides*)

The results of the average taste ratings from 1971 are similar to those of 1972, since the ranking scores differed by an average of only 1.1 units. Subsequently, it cannot be concluded that any one sample tasted significantly better or worse than any other samples. However, since the fish from the treated ponds were rated higher, in some cases, than those of Control Pond, it can be concluded that treatment of the aquatic systems with outboard engine emissions had no detrimental effect on the taste of the fish.

These findings are not in agreement with the results reported by English et al. (11, 12) in which they found evidence of tainting. They contend that tainting occurs at ratios as low as 6.8 gal. of burned fuel to 10^6 gal. of water. The only readily apparent difference in the two studies is in the confinement of the fish. English used live boxes to hold the fish for stressing, whereas in this study the fish swam freely throughout the pond and were caught by angling and netting. Lack of ability to move freely in the lake system may account for increased tainting although testing of this hypothesis by using live boxes in the southern lakes was not done.

The lack of tainting in the southern lake study was first hypothesized to be attributable to fish distribution. The assumption was made that noise and turbulence from engines scattered fish to the far shore of the pond. In effect, this would remove fish from the area where tainting could occur. However, schools of sunfish were often observed swimming in the backwash of the propellers. Furthermore, recent hydrocarbon testing has shown that the distribution of aromatic emissions were elevated throughout the ponds, although values beside the engines are approximately twice those in remote pond areas.

In conclusion, fish tainting resulting from outboard motor emissions did not occur in the species of sunfish and bass.

SECTION X

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APPENDIX A

WATER BUDGET

The test ponds are located in a region of permeable sands underlain by an impermeable layer of clays. This layer of clays isolates percolated surface waters from the aquifer, creating what is termed a perched water table. Perched water tables are usually localized.

In order to determine if in fact the test ponds were isolated bodies of water throughout the study period, and not directly influenced by the aquifer, measurements were made of rainfall, evaporation, and water levels at each of the test ponds. A water budget for the test ponds was then created and evaluated.

FIELD PROCEDURES

Rainfall was measured by three standard rain gauges; each located within 30 yards of a test pond. These gauges were read and data recorded at approximately one week intervals. Rainfall was measured to 0.01 of an inch.

Direct measurement of evaporation from the two treated ponds was made by the use of floating evaporation pans. These pans were 0.75 meters on a side and 30 cm in depth, and were constructed out of clear 1/4 inch plexiglass. Flotation was assured by use of styrofoam strips along the centerline of the pan sides. A reference post was located in the center of the pan, and the pan was filled with water to the top of the post. At subsequent readings of the pan the amount of water added to removed to restore the water level to the reference height was recorded. From the change in volume, the change in pan water level was calculated and this figure was then corrected for the rainfall recorded during the measurement period.

Water levels were recorded in each of the test ponds. The technique used was to measure the perpendicular distance from a reference stud at a known elevation (relative to the topographic maps prepared early in the project, see Figures A1 and A2) to the water surface. These figures were then corrected to give the relative elevation of the water surface from the zero contour level.

A water budget was constructed by examining the water loss through evaporation and the water gain through rainfall. Change in pond elevation was predicted based solely on these two parameters, and then compared with the actual measured change in elevation during the measurement period. Predicted versus actual changes were compared for all dates where sufficient information existed. It was assumed that if the predicted and actual water levels could be shown to be statistically similar, then rainfall and evaporation could be considered the primary influence on water levels in the pond and, by inference, ground water of minor importance.

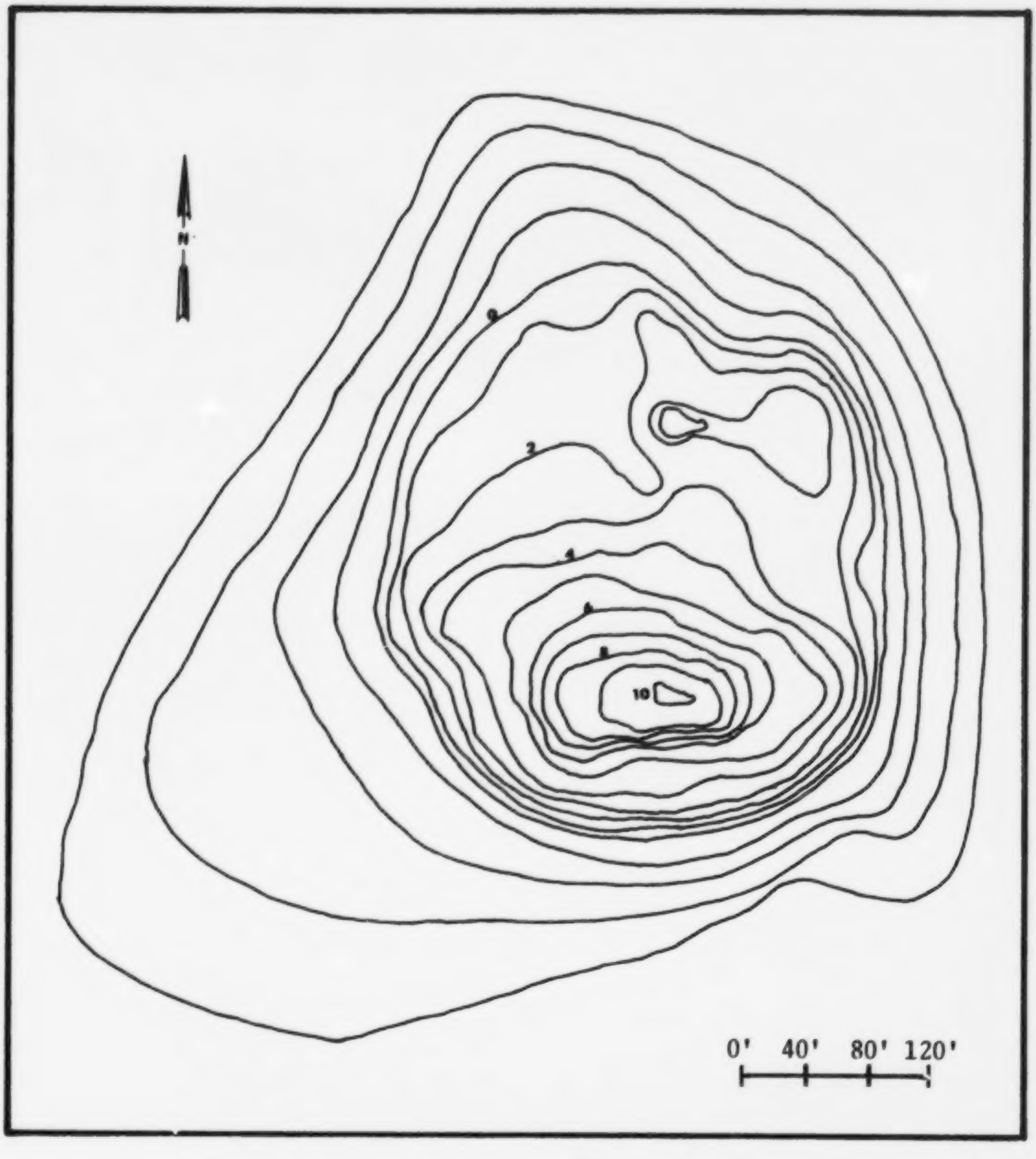
N
0
2
4
6
8
10
0' 40' 80' 120'

Figure A1. Topographic contour map of the Drained Engine Pond. Contour intervals are at 1'.

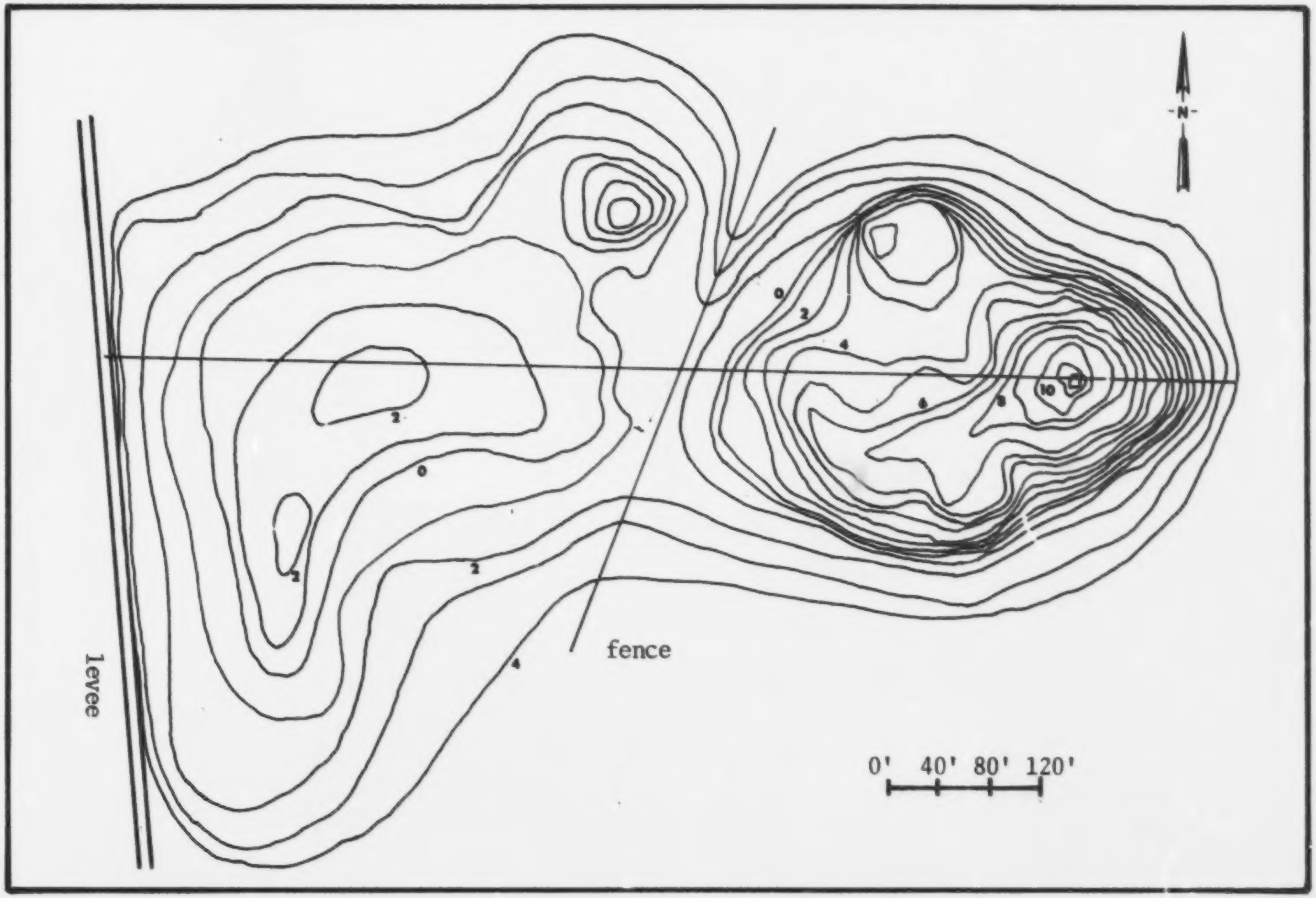
N
0
2
4
6
8
10
2
0
2
2
4
fence
levee
0' 40' 80' 120'

Figure A2. Topographic contour map of the Drainless Engine Pond, showing locations of the levee and the fence. Contour intervals are at 1'.

RESULTS

Table A1 contains the physical measurements of evaporation, rainfall, and water level made during the study period. Total rainfall, measured during the project was as follows:

		Drainless	Drained	Control
July-Dec.	1971	97.8 cm	96.6 cm	102.3 cm
Jan.-Dec.	1972	124.0 cm	124.5 cm	122.5 cm
Jan.-Aug.	1973	38.5 cm	38.2 cm	35.8 cm

The pond water levels ranged from lows of around -40 cm in late January and early February, 1973, to highs of 120 cm in the Drainless Engine Pond and 140 cm in the Drained Engine Pond in October, 1971. The water levels in the test ponds remained very similar througout the project period. Water levels in general increased during the first half of the project and dropped during the last half.

The results of the water budget calculations based on the above data are given in Table A2. If the predicted values adequately describe the actual values the mean of the population of differences between the values should equal zero. Applying a two-tailed t-test (47), no significant difference at the 99 percent confidence level was found between the two sets of values. The statistical results are summarized as follows:

Drainless Engine Pond - Means for group are:
Predicted= - 1.7474 Actual= -1.8045
Mean difference is 0.0571
SEM = 0.2930
t (Matched Pairs) = 0.1950 DF = 65
The table value for $t_{.01}$(60 d.f.) = 2.7

Drained Engine Pond - Means for group are:
Predicted= -2.1610 Actual= -2.4220
Mean difference is 0.2610
SEM = 0.4910
t (Matched Pairs) = 0.636 DF = 58
The table value for $t_{.01}$(60 d.f.) = 2.7

DISCUSSION

It was assumed that if all sources of input and discharge from the ponds were known and measured, the water level at any time could be determined. Possible sources of water into the ponds include rainfall, surface flows, surface runoff, groundwater seepage, and sublacustrine springs. Possible sources of discharge from the ponds

Table A1. A record of physical data recorded for the test ponds. 1971.

Date	Control	Drainless			Drained		
	Rainfall (cm)	Rainfall[a] (cm)	Evaporation[b] (cm)	Water Level[c] (cm)	Rainfall (cm)	Evaporation (cm)	Water Level (cm)
7 13 71	2.54	1.40			2.36		
7 16 71	0.15	0.10			0.04		
7 19 71	0.84	0.56			1.30		
7 20 71	5.59	3.81			0.15		
7 22 71	2.24	1.96			2.11		
7 28 71	2.77	1.85		25.00	2.67		52.10
8 2 71	15.04	13.59		43.80	12.45		72.70
8 3 71	0.03	0.03		43.80	2.36		73.30
8 5 71	0.15				0.10		
8 6 71		1.52			2.11		
8 9 71	1.52	0.10		42.50	0.20		78.90
8 12 71	5.84	7.37		53.80	6.76		
8 17 71	15.24	15.06		77.50	17.22		121.30
8 23 71	2.03	4.45			4.39		
8 25 71	0.25	0.84	0.68	92.90	0.00		124.80
8 27 71	8.26	5.72	0.25	103.50	6.95		
8 30 71	1.19	0.17	1.44	104.20	2.92	0.78	131.60
9 1 71	0.05	0.18	1.22	104.50	1.32	0.71	134.30
9 7 71		0.00	2.31	102.50	0.00	0.26	132.60
9 10 71	0.48	0.46	0.66	103.00	0.25	0.43	132.60
9 15 71	1.09	1.02	1.54		0.66	1.43	131.50
9 21 71	0.94	1.02	2.02		0.74	2.14	
9 22 71		0.00	0.08		0.00	0.38	128.30
9 24 71		0.00	0.85	94.50	0.00	0.94	
9 29 71	0.43	0.28	1.79	97.5		2.74	122.30
10 1 71		0.00	0.91	96.50	0.00		121.00
10 4 71		0.00	1.03	93.00	0.00		118.30
10 7 71		0.00	0.87	92.50	0.00		114.80
10 8 71	2.00	2.29	0.73	92.50	2.00		114.80
10 11 71	8.84	8.84	0.59	104.50	8.41		132.00

[a] measured by a standard rain gauge and converted from inches to centimeters
[b] evaporation pan data: see text for details
[c] water level measured from the zero contour of the topographic maps

Table A1. Continued

Date	Control	Drainless			Drained		
	Rainfall (cm)	Rainfall[a] (cm)	Evaporation[b] (cm)	Water Level[c] (cm)	Rainfall (cm)	Evaporation (cm)	Water Level (cm)
10 13 71		0.00	0.40	94.50	0.03	0.43	132.30
10 15 71	4.90	4.47		111.50	2.92		137.30
10 18 71		7.01		120.50	5.08		143.30
10 20 71	0.03	0.05	0.65	119.00	0.00	0.80	141.30
10 22 71					0.00	0.16	140.30
10 25 71	0.25	0.18	0.78	118.50	0.25	0.50	138.20
10 29 71	0.08	0.00	1.01	118.50	0.00	1.21	138.30
11 4 71	0.56	0.38	1.01	117.20	0.91		136.50
11 5 71		0.00	0.40	117.00	0.00	0.57	135.70
11 8 71		0.00	0.67	114.50	0.00	0.89	132.00
11 9 71		0.00	0.40	114.50	0.00	0.40	131.30
11 10 71	0.30	0.30	0.14	112.50	0.33	0.45	130.00
11 11 71		0.00	0.03	114.10	0.00	0.02	127.70
11 12 71		0.00	0.63	113.40	0.00	0.51	129.20
11 15 71		0.00	0.61	112.10			
11 17 71		0.00	0.21	111.60	0.00	0.22	126.20
11 18 71		0.00	0.20	111.00	0.00	0.20	125.40
11 23 71		0.08	1.20	108.40	0.18	1.32	121.40
12 6 71	8.10	7.37	0.53	114.90	8.64		129.70
12 7 71		0.00	0.28	114.70	0.00	0.29	129.50
12 8 71		0.00	0.11	114.70	0.00	0.08	129.10
12 10 71		0.00	0.17	114.40	0.00	0.15	128.20
12 13 71		0.00	0.10	114.30	0.00	0.08	127.70
12 16 71		0.00	0.14	114.00	0.00	0.15	127.40
12 20 71		0.00	0.08	113.60	0.00	0.09	127.10
12 22 71	2.06	2.13	1.69	114.40	1.55	1.83	127.60
12 28 71	2.79	3.20	2.72	115.30	3.73	4.27	129.00

[a] measured by a standard rain gauge and converted from inches to centimeters
[b] evaporation pan data: see text for details
[c] water level measured from the zero contour of the topographic maps

Table A1. Continued.

Date	Control	Drainless			Drained		
	Rainfall (cm)	Rainfall[a] (cm)	Evaporation[b] (cm)	Water Level[c] (cm)	Rainfall (cm)	Evaporation (cm)	Water Level (cm)
1 5 72	2.11	2.03	3.56	110.60	2.11	3.85	122.30
1 11 72	2.49	2.44	2.12		2.21	2.49	127.40
1 12 72	0.00	0.00	2.22	108.60	0.00	2.11	120.30
1 19 72	4.14	4.06	3.52	110.60	4.11	3.21	121.30
1 26 72	9.65	9.63		113.60	9.65		135.30
2 2 72	2.59	2.54	3.44	115.10	2.49	3.37	125.30
2 9 72	0.00	0.00	2.17	110.60	0.00	2.21	122.30
2 16 72	0.25	0.00	2.24	108.10	0.00	2.27	118.30
2 23 72	3.30	2.98	3.28	103.60	2.97	3.27	114.30
3 1 72	5.26	4.88		106.60	4.72		116.30
3 8 72	0.00	0.00	1.74	108.60	0.00	1.75	118.30
3 15 72	0.00	0.00	8.05	104.60	0.00	8.05	114.30
3 22 72	0.51	0.28	2.53	99.10	0.33	2.54	108.30
3 29 72	0.00	0.00	6.44	96.10	0.00	6.44	105.80
4 5 72	0.00	0.00	8.06	89.60	0.00	8.05	99.30
4 12 72	13.21	12.78		94.60	12.78		94.30
4 19 72	0.00	0.00	6.81	90.60	0.00	6.94	90.30
4 26 72	6.35	6.35		89.60	6.35		99.30
5 3 72	0.00	0.00	4.23	86.60	0.00	4.27	96.30
5 10 72	2.54	2.39	3.14	79.60	2.44	3.17	99.30
5 17 72	9.14	9.14		79.60	9.14		99.30
5 24 72	1.22	1.02	2.04	77.60	1.07	2.13	87.30
5 31 72	8.51	8.51		79.60	8.51		99.30
5 7 72	0.00	0.00	3.90	75.60	0.00	3.94	85.30
6 16 72	0.00	0.00	3.31	73.60	0.00	3.22	82.80
6 23 72	14.00	14.02		75.60	14.02		85.30
6 30 72	0.00	0.00	8.05	67.60	0.00	8.05	77.30
7 7 72	0.89	0.76	6.50	59.60	0.79	6.52	69.30
7 14 72	0.00	0.00	5.23	53.60	0.00	5.23	63.30
7 24 72	0.76	0.79	8.05	48.60	0.66	8.05	57.30

[a] measured by a standard rain gauge and converted from inches to centimeters

[b] evaporation pan data: see text for details

[c] water level measured from the zero contour of the topographic maps

Table A1. Concluded.

Date	Control	Drainless			Drained		
	Rainfall (cm)	Rainfall[a] (cm)	Evaporation[b] (cm)	Water Level[c] (cm)	Rainfall (cm)	Evaporation (cm)	Water Level (cm)
7 31 72	0.00	0.61	8.05	40.10	0.66	8.05	49.80
8 7 72	19.60	19.63		49.60	19.63		59.30
8 14 72	3.20	3.15	5.95	46.60	3.20	6.17	56.30
8 21 72	8.76	8.76		49.10	8.76		58.80
8 28 72	0.00	0.00	3.17	45.60	0.00	3.26	55.30
9 4 72	0.00	0.00	6.12	40.60	0.00	6.11	50.30
9 13 72	3.51	2.08			2.08		
9 20 72	0.00	0.00	1.91	22.60	0.00	0.22	26.30
9 26 72	0.00	0.00	8.05	12.60	0.00	8.05	26.30
10 4 72	0.00	0.00	8.05	7.60	0.00	7.54	13.30
10 11 72	0.00	0.00	3.03	1.60	0.00	3.15	7.30
10 18 72	0.00	0.00	2.62	-5.40	0.00	3.98	0.30
10 25 72	0.00	0.00	7.57	-11.40	0.00	7.99	-3.70
12 22 72	0.20	4.70	1.08	-25.40	5.21	1.63	-27.70
1 5 73	0.18	0.13	0.73	-25.40	0.08	0.56	-26.70
1 12 73	2.54	2.54			2.92		
1 19 73	0.00	0.13		-37.40	0.23	0.23	-40.70
1 24 73	2.69	2.77	1.79	-36.40	2.84	1.59	-40.20
2 2 73	4.32	4.60		-34.40	5.38		-35.20
2 9 73	2.79	2.59		-52.80	2.21	1.89	-35.00
2 16 73	3.30	2.72		-38.40	3.05		-17.70
2 23 73	0.08	0.08	1.89	-30.40	0.13	1.43	-31.70
3 2 73	0.03	0.03	1.70	-31.90	0.00	1.77	-35.70
3 12 73	6.53	6.48	1.79	-25.40	7.80	2.24	-25.70
3 16 73	0.00	0.00	1.41	-25.90	0.00	1.39	-26.20
3 26 73	10.62	9.96		-14.90	9.53		-12.70
4 12 73	3.68	3.81		-8.40	4.06		-3.70

[a] measured by a standard rain gauge and converted from inches to centimeters
[b] evaporation pan data: see text for details
[c] water level measured from the zero contour of the topographic maps

Table A2. Predicted and actual changes in the water levels of the BIA test ponds for all dates where sufficient data was available to calculate predicted change.

	Change in Water Level			
	Drainless		Drained	
Date	Predicted	Actual	Predicted	Actual
9 1 71	-1.04	0.30	0.61	2.70
9 7 71	-2.31	-2.00	-0.26	-1.70
9 10 71	-0.20	0.50		
9 15 71			-0.77	-1.10
10 13 71	-0.40	-10.00	-0.40	0.30
10 25 71			-0.25	-2.10
10 29 71			-1.21	0.10
11 5 71	-0.40	-0.20	-0.57	-0.80
11 8 71	-0.67	-2.50	-0.89	-3.70
11 9 71			-0.40	-0.70
11 10 71	0.16	-2.00	-0.12	-1.30
11 11 71	-0.03	1.60	-0.02	-2.30
11 12 71	-0.63	-0.70	-0.51	1.50
11 18 71	-0.20	-0.60	-0.20	-0.80
11 23 71	-1.12	-2.60	-1.14	-4.00
12 7 71	-0.28	-0.20	-0.29	-0.20
12 8 71	-0.11	0.00	-0.08	-0.40
12 10 71	-0.17	-0.30	-0.14	-0.90
12 13 71	-0.10	-0.10	-0.08	-0.50
12 16 71	-0.14	-0.30	-0.15	-0.30
12 20 71	-0.09	-0.40	-0.09	-0.30
12 22 71	0.44	0.80	-0.28	0.50
12 28 71	0.48	0.90	-0.54	1.40
1 11 72			-0.28	5.10
1 12 72			-2.11	-7.10
1 19 72	0.54	2.00	0.90	1.00
2 2 72	-0.90	1.50		
2 9 72	-2.17	-4.50	-2.21	-3.00
2 16 72	-2.24	-2.50	-2.27	-4.00
2 23 72	-0.30	-4.50	-0.30	-4.00
3 8 72	-1.74	2.00	-1.75	2.00
3 15 72	-8.05	-4.00	-8.05	-4.00
3 22 72	-2.25	-5.50	-2.21	-6.00
3 29 72	-6.44	-3.00	-6.44	-2.50
4 5 72	-8.05	-6.50	-8.05	-6.50
5 3 72	-4.23	-3.00	-4.27	-3.00
5 10 72	-0.75	-7.00	-0.73	3.00
5 24 72	-1.02	-2.00	-1.06	-12.00
6 7 72	-3.90	-4.00	-3.94	-14.00
6 16 72	-3.31	-2.00	-3.22	-2.50
6 30 72	-8.05	-8.00	-8.05	-8.00
7 7 72	5.74	-8.00	-5.73	-8.00

Table A2. Continued.

	Change in Water Level			
	Drainless		Drained	
Date	Predicted	Actual	Predicted	Actual
7 14 72	-5.23	-6.00	-5.23	-6.00
7 24 72	-7.26	-5.00	-7.39	-6.00
7 31 72	-7.44	-8.50	-7.39	-7.50
8 14 72	-2.80	-3.00	-2.97	-3.00
8 28 72	-3.17	-3.50	-3.26	-3.50
9 4 72	-6.12	-5.00	-6.11	-5.00
9 26 72	-8.05	-10.00		
10 4 72	-8.05	-5.00	-7.54	-13.00
10 11 72	-3.03	-6.00	-3.15	-6.00
10 18 72	-2.62	-7.00	-3.98	-7.00
10 25 72	-7.57	-6.00	-7.99	-4.00
12 29 72				
1 24 73	0.98	1.00	1.25	0.50
2 9 73			0.32	0.20
3 2 73	-1.67	-1.50	-1.77	-4.00
3 12 73	4.69	6.50	5.56	10.00
3 16 73	-1.41	-0.50	-1.39	-0.50

include evaporation, seepage into the aquifer, transpiration from emergent and terrestrial vegetation, direct channeling to the aquifer, and surface discharge.

Of the water sources, sublacustrine springs can be eliminated from consideration upon examination of the pond water chemistry. Aquifer waters in Florida have a relatively high pH (7-8) and are quite hard, while the water found in the ponds is soft and low (4-6) pH.

There are no surface flows into the ponds, and surface runoff would only direcly occur during the most severe rains. The surrounding soil consists of extremely porous sands capable of almost immediate percolation for all but the heaviest subtropical downpour. Seepage from these surrounding sands undoubtably occurs, and seepage at a low rate from the aquifer is possible.

Of the avenues of water loss from the ponds only direct channeling to the aquifer and surface discharge may be summarily removed from the list of possibilities.

Hutchinson (16) states that evaporation pan data when extended to entire lakes is usually biased, namely, more evaporation is predicted than in fact occurs. Evaporation from a body of water is a function of a number of variables. The more important of these are: air temperature, surface water temperature, winds, water circulation, relative humidity, and barometric pressure. Hutchinson feels that good evaporation pan data is usally about 10% in excess of the actual evaporative loss.

We must, therefore, evaluate our ability to obtain a working water budget based strictly on the rainfall and evaporation measurements obtained in the field in light of the above. Four possibilities present themselves:

1. The evaporation figures are not in excess, and all water loss and gain is attributable to rainfall and evaporation.

2. That an unmeasured amount of water equal to the error of the evaporation figure enters the pond through seepage from the surrounding sands (more probable) or the aquifer (less probable).

3. That transpiration losses equal in magnitude the error of the evaporation pan data.

4. Some combination of 2 and 3.

SUMMARY

1. A predictive water budget may be created by consideration of only rainfall and evaporation data collected for the test ponds.

2. Evaporation pan data is probably biased towards greater amounts of evaporation than actually occurred.

3. The error of the evaporation data is probably on the order of 10 percent or less.

4. The amount of error must be balanced by either water loss due to transpiration or seepage, or water gain in excess of rainfall by seepage, or some combination thereof.

5. Rainfall and evaporation account for at least 90 percent of all water changes in the ponds.

6. Therefore, the test system is considered to have remained unaffected by the aquifer throughout the study period.

APPENDIX B

TREATMENT LEVELS

The treatment levels during the project did not remain at a constant rate due to a continuous fluctuation of the water levels in the ponds. Figures B1 through B6 show pond water levels and the calculated corresponding water volumes for the course of the study. Water levels are given in centimeters from the zero contour of the topographic maps of each pond. This contour represents the water level at the time of the survey. Water volumes are limited in accuracy (± 5 percent) by the size of the contour interval. These volumes are represented in the figures as a percentage of the original volume as of June, 1971.

During periods of high water, the Drainless Pond rose above a shallow ridge separating it from an adjacent water-filled depression. At the time of the highest water, the bridge between the ponds was about 2 1/2 feet deep and over 200 feet wide. While we feel that it is unlikely that significant water exchange between the two ponds occurred, volume figures were prepared for both the united pond volume and the eastern (motor containing) pond. The volume of water contained in the western pond was not added to the total pond volume until the water at the ridge was in excess of six inches deep. Below this level the shoreline vegetation afforded an effective barrier against interpond water circulation.

Figures B7 through B9 represent treatment levels of the test ponds over the period of the study, as calculated from the derived water volume figures. Treatments are given in terms of a multiplier of the calculated 'normal usage' rate. Treatment levels are directly calculated from water volumes, and must also be limited to a precision of ± 5 percent. The optimal treatment level of 3X was not attained until October, 1972, when the water had receded to its original (June, 1971) level. The treatment level continued at values of 3X or greater for the remainder of the project.

Figure B10 illustrates the cumulative volume of fuel burned in liters per thousand liters of water present. Table B1 lists the actual value calculated for each of the days during motor operation on which water volume information is available.

Figure B11 shows the daily volume of fuel burned in liters per thousand liters of water present on a given date. Table B1 contains the calculated values which were used in creating this graph. Daily concentrations in the test ponds ranged from 0.0045 - 0.0476 percent (percent fuel volume to water volume) in the Drainless Engine Pond (0.132 - 0.0476 percent if the spillover pond is not added at high water levels) and 0.0069 - 0.0470 percent for the Drained Engine Pond.

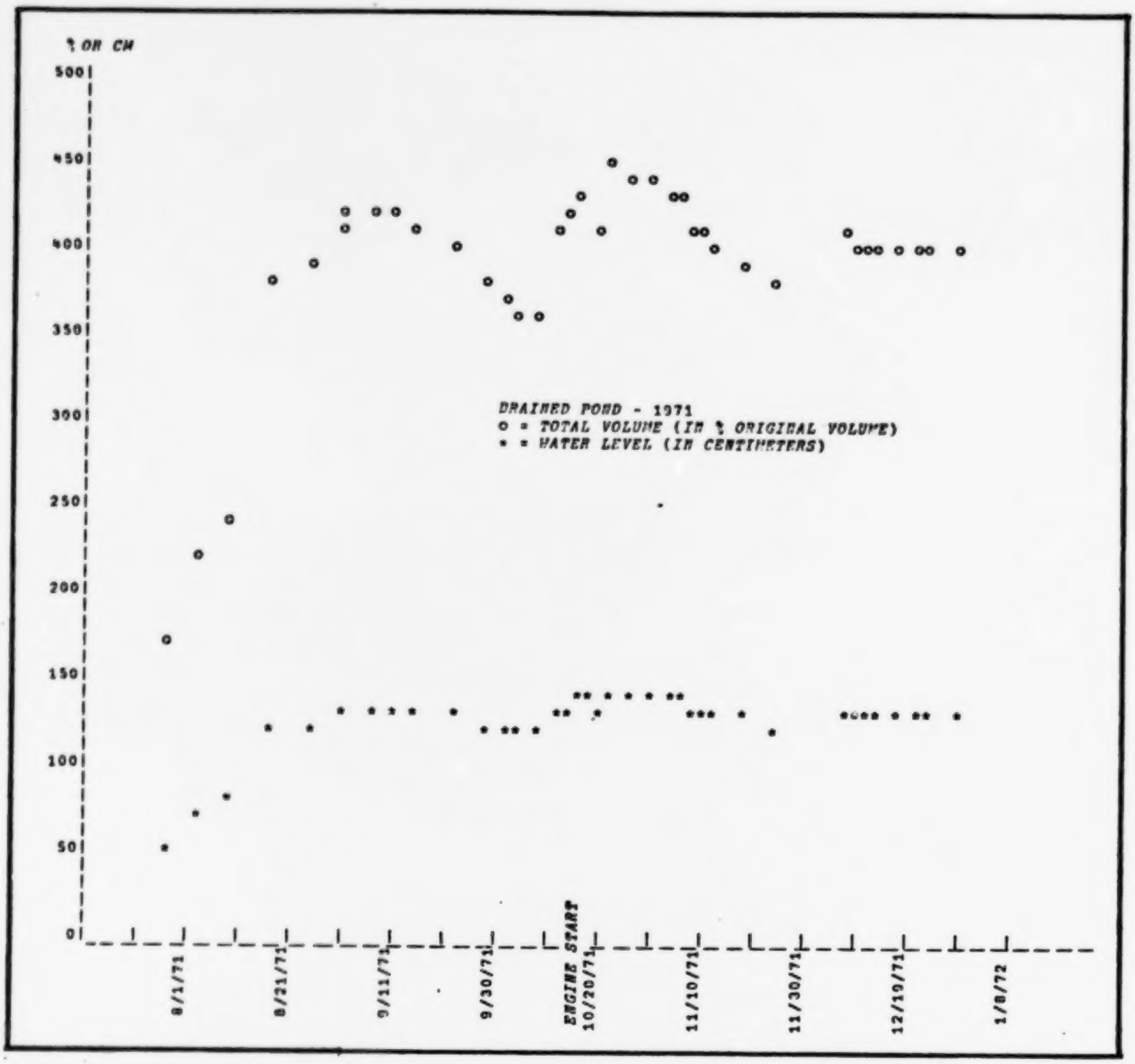

Figure B1. Water levels and relative water volumes for the Drained Test Pond during 1971. Water levels are measured in centimeters from the zero contour interval. Water volumes are given in percent of zero contour (May 1971) volumes.

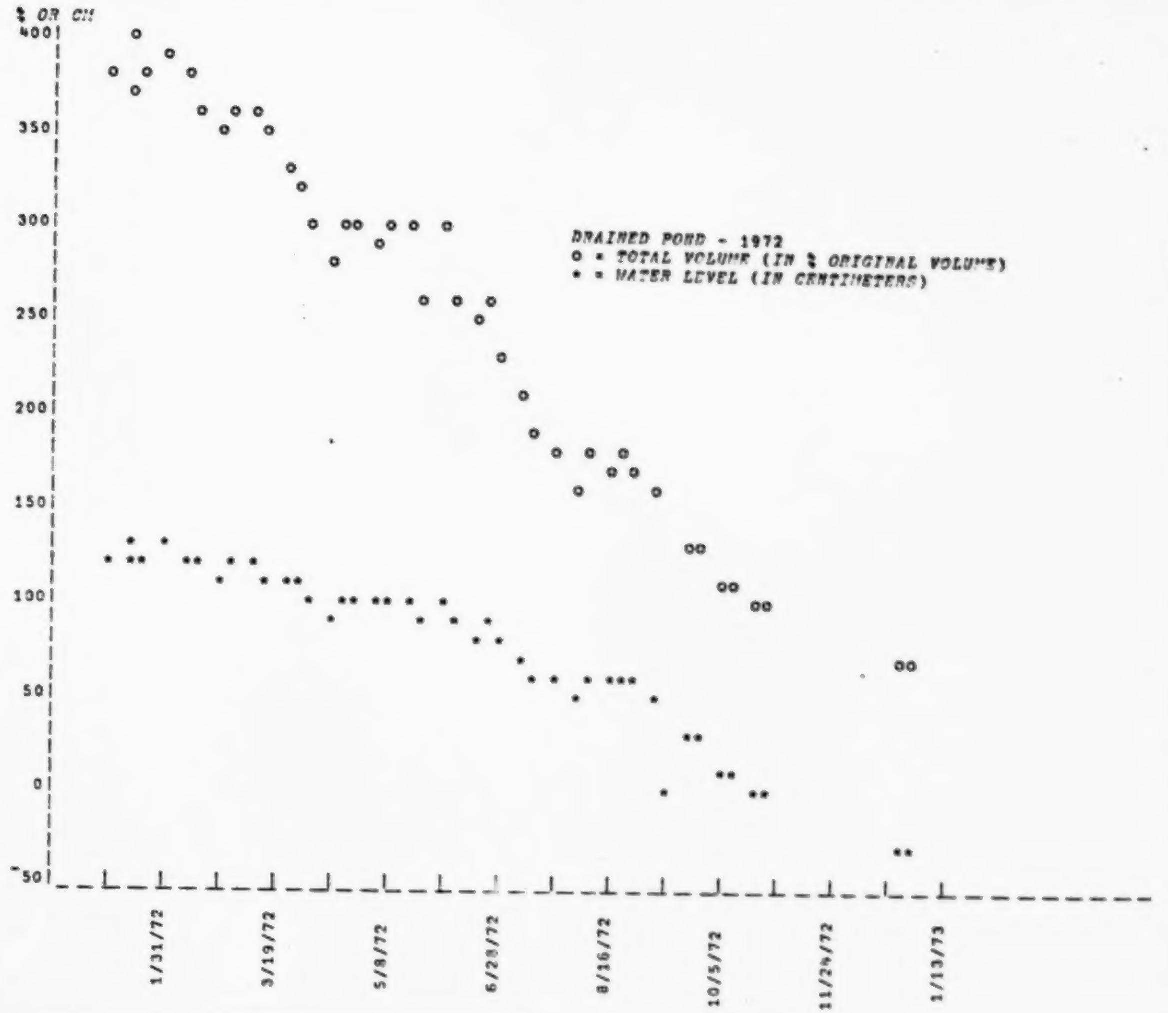

Figure B2. Water levels and relative water volumes for the Drained Test Pond during 1972. Water levels are measured in centimeters from the zero contour interval. Water volumes are given in percent of zero contour (May 1971) volumes.

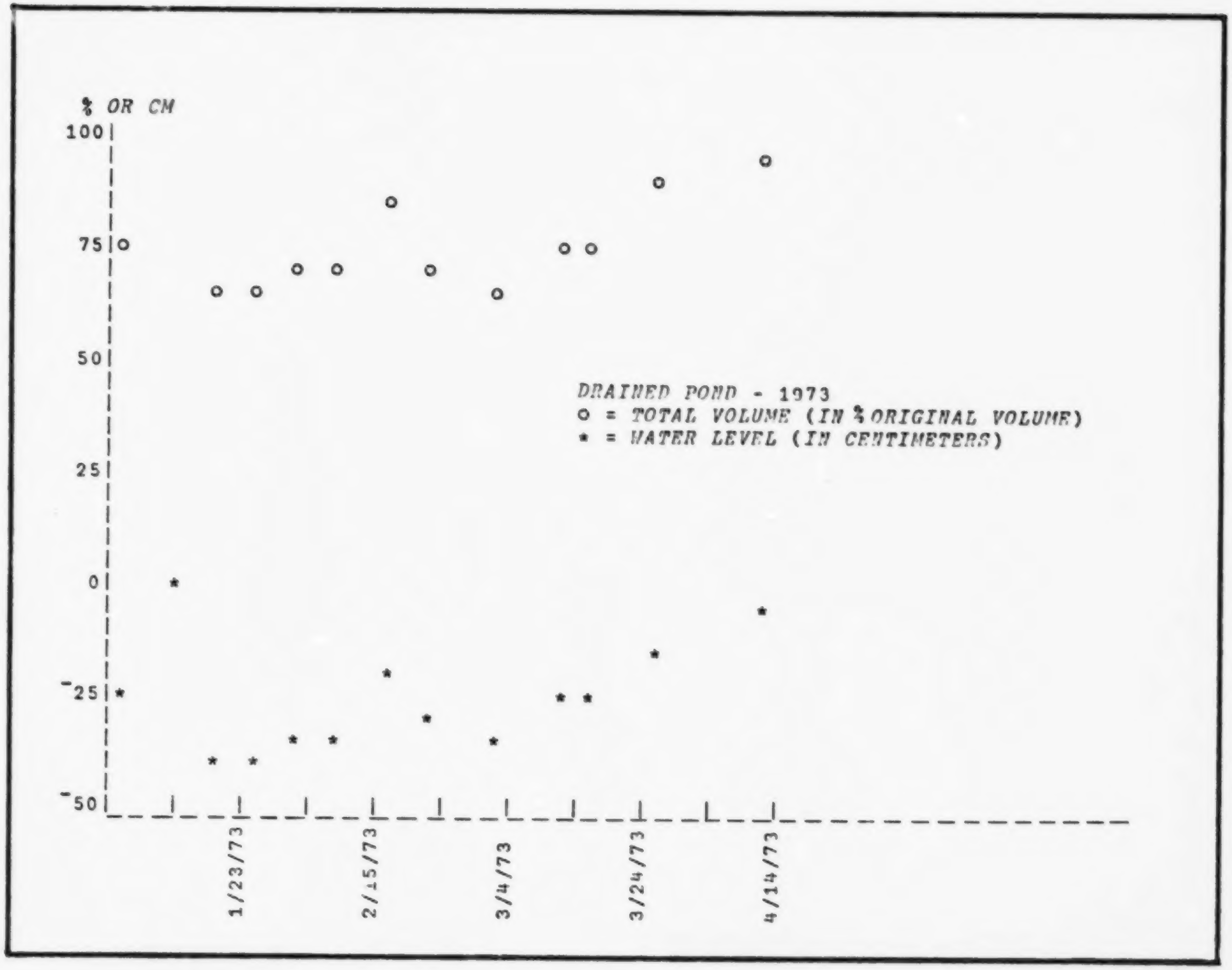

Figure B3. Water levels and relative water volumes for the Drained Test Pond during 1973. Water levels are measured in centimeters from the zero contour interval. Water volumes are given in percent of zero contour (May 1971) volumes

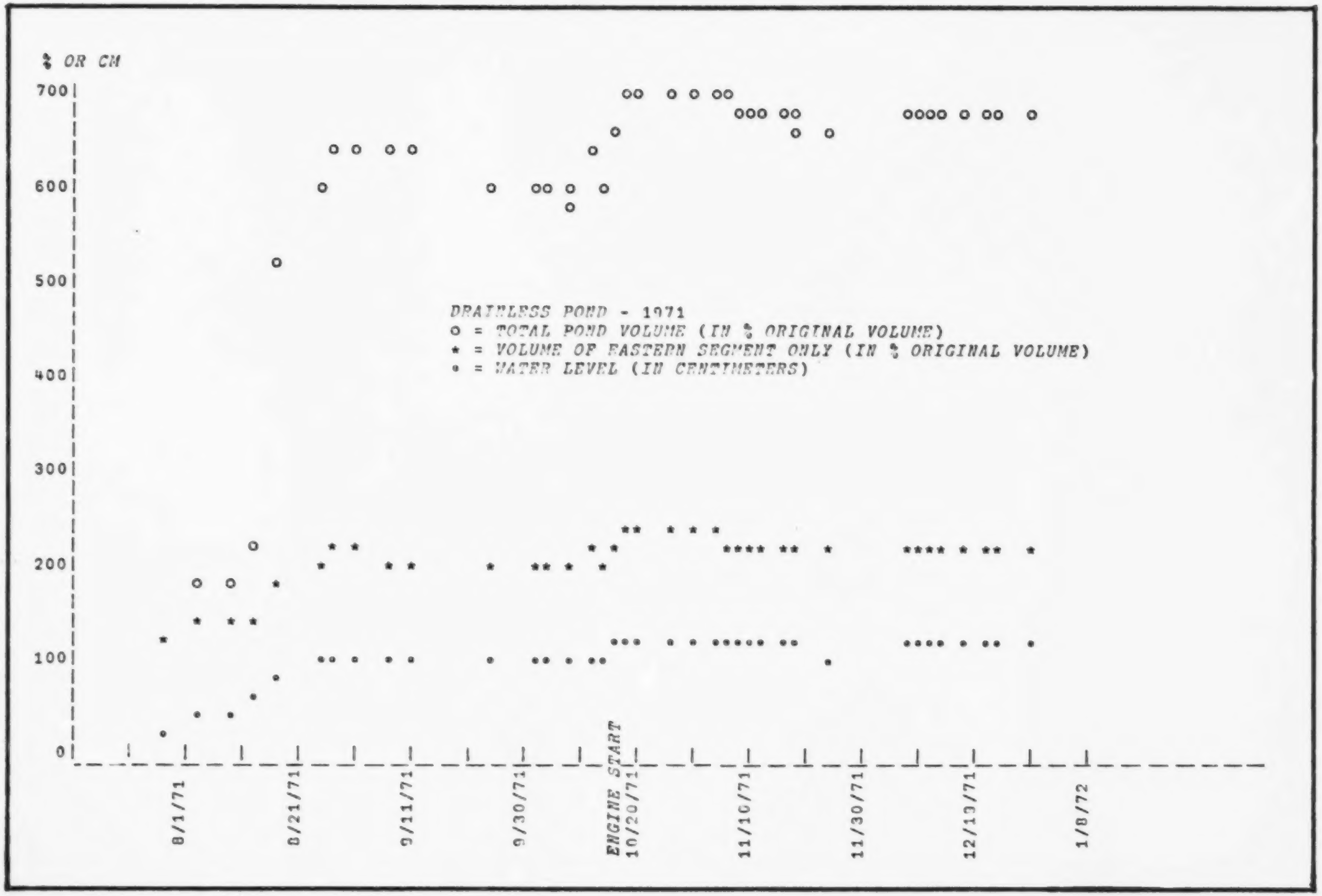

Figure B4. Water levels and relative water volumes for the Drainless Test Pond during 1971. Water levels are measured in centimeters from the zero contour interval. Water volumes are given in percent of the zero contour (May 1971) volumes. Eastern segment volumes consider only the motor containing pool. Total volumes include an adjacent pool when the two pools are adjoined by greater than 6" of water (see text).

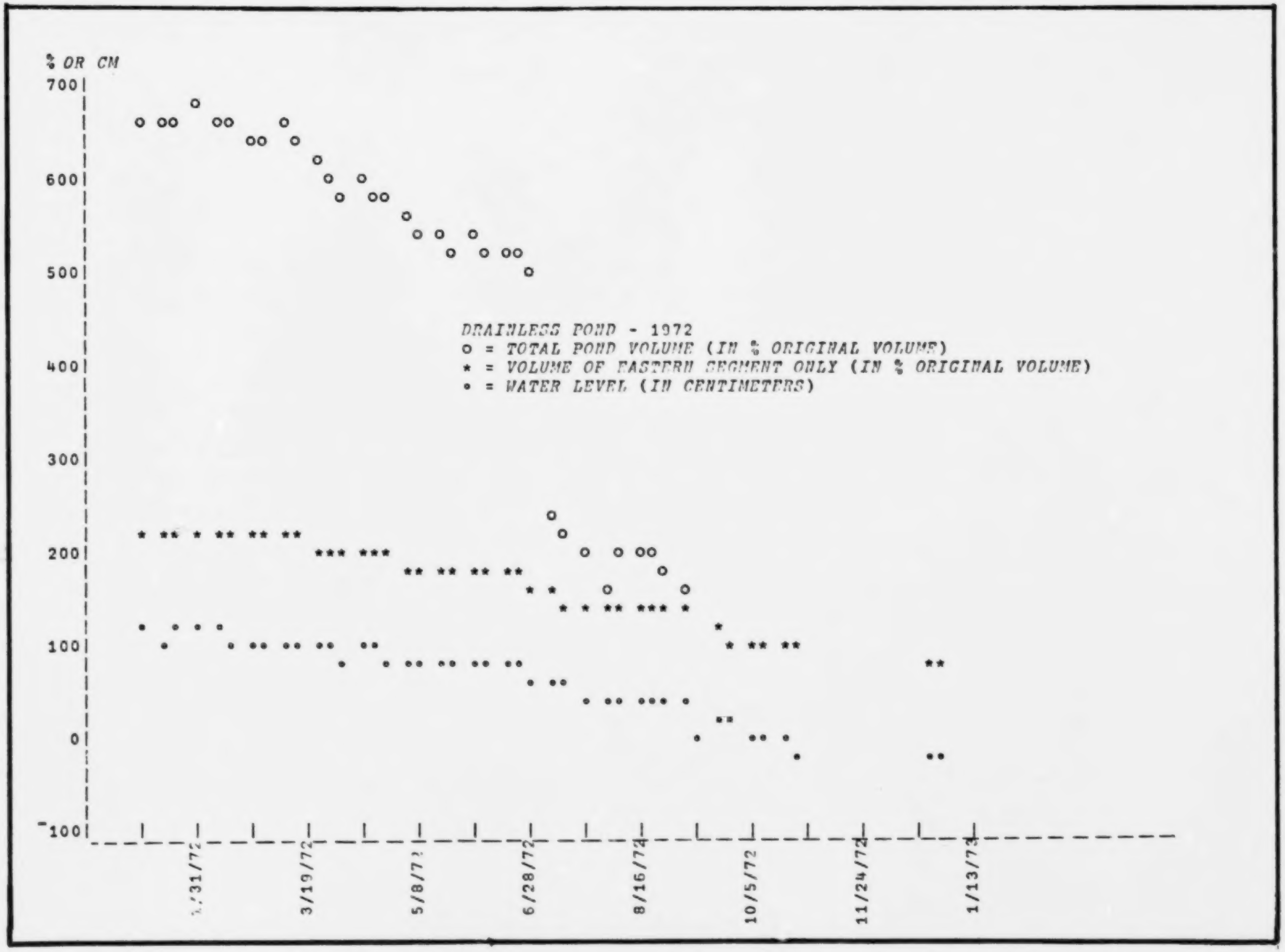

Figure B5. Water levels and relative water volumes for the Drainless Test Pond during 1972. Water levels are measured in centimeters from the zero contour interval. Water volumes are given in percent of the zero contour (May 1971) volumes. Eastern segment volumes consider only the motor containing pool. Total volumes include an adjacent pool when the two pools are adjoined by greater than 6" of water (see text).

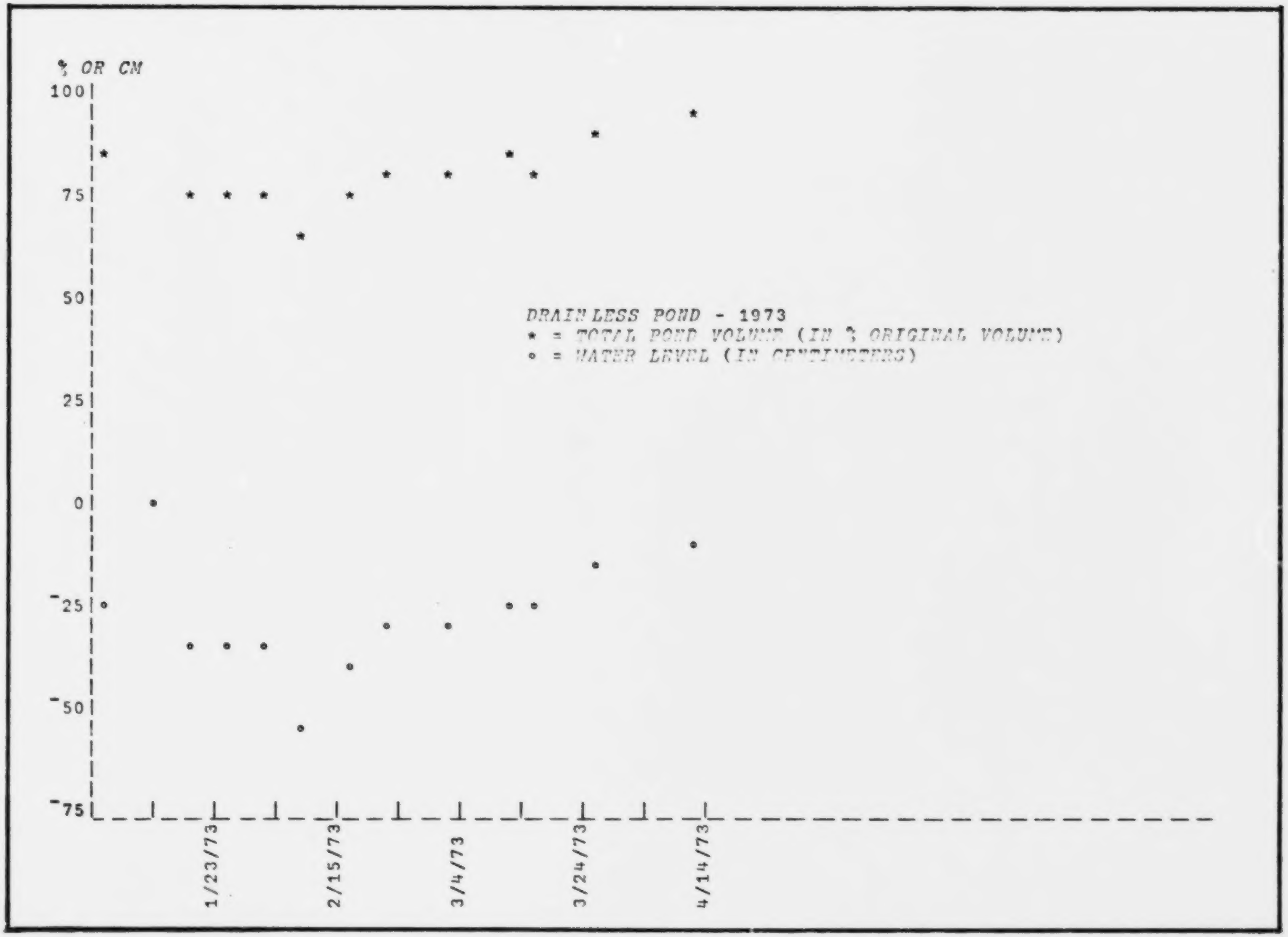

Figure B6. Water levels and relative water volumes for the Drainless Test Pond during 1973. Water levels are measured in centimeters from the zero contour interval. Water volumes are given in percent of the zero contour (May 1971) volumes. Eastern segment volumes consider only the motor containing pool. Total volumes include an adjacent pool when the two pools are adjoined by greater than 6" of water (see text).

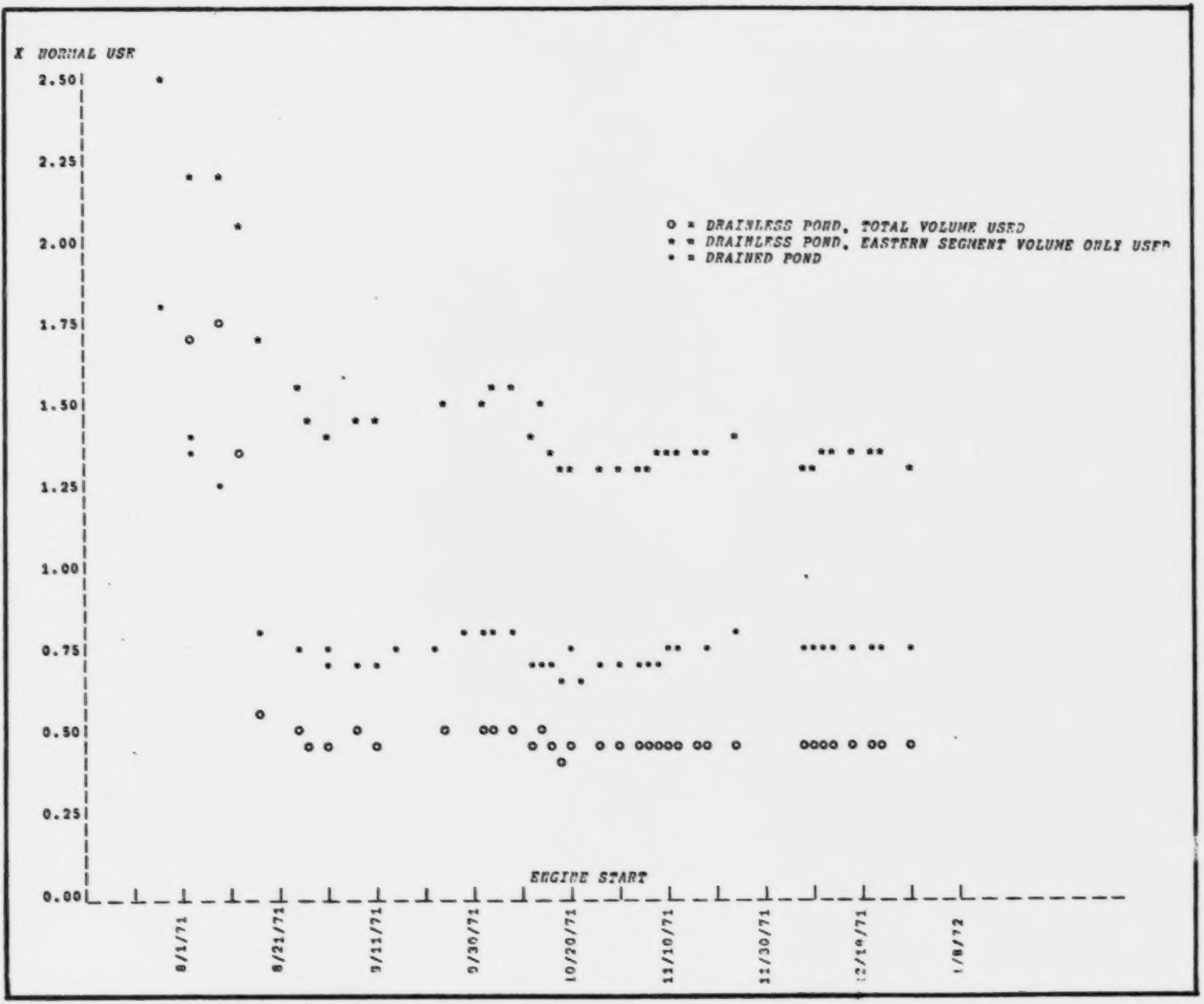

Figure B7. Actual treatment levels for Drainless and Drained Test Ponds during 1971. Treatment levels are given in terms of a multiplier times normal usage rate (see Appendix C calculations). Actual levels varied due to changes in water volumes present. Two levels are given for Drainless Pond when the eastern segment adjoined the western pool. The actual level would be dependent on the degree of mixing between the two pools, and probably ties between the two values plotted.

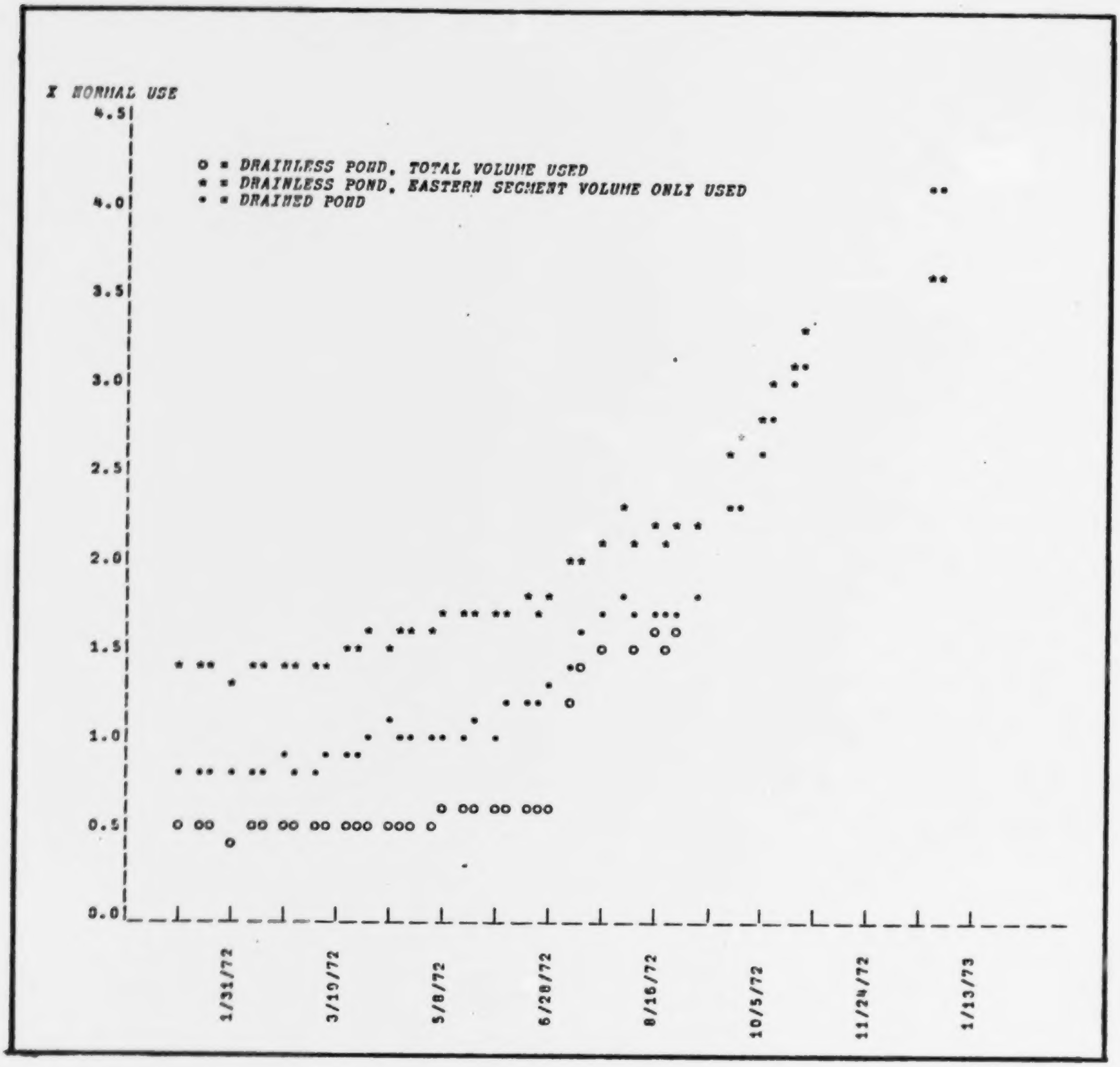

Figure B8. Actual treatment levels for Drainless and Drained Test Ponds during 1972. Treatment levels are given in terms of a multiplier times normal usage rate (see Appendix C calculations). Actual levels varied due to changes in water volumes present. Two levels are given for Drainless Pond when the eastern segment adjoined the western pool. The actual level would be dependent on the degree of mixing between the two pools, and probably ties between the two values plotted.

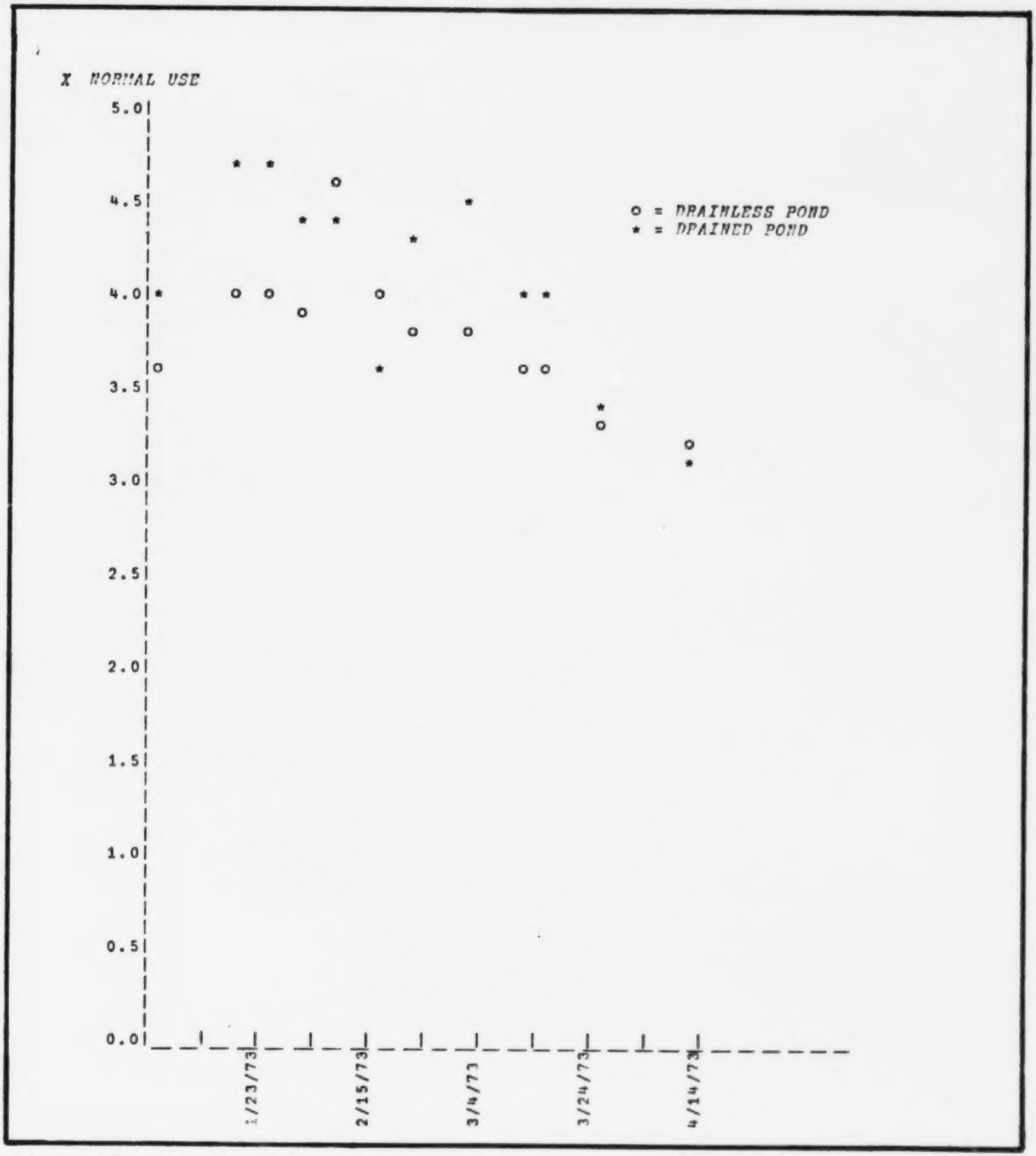

Figure B9. Actual treatment levels for Drainless and Drained Test Ponds during 1973. Treatment levels are given in terms of a multiplier times normal usage rate (see Appendix C calculations). Actual levels varied due to changes in water volumes present.

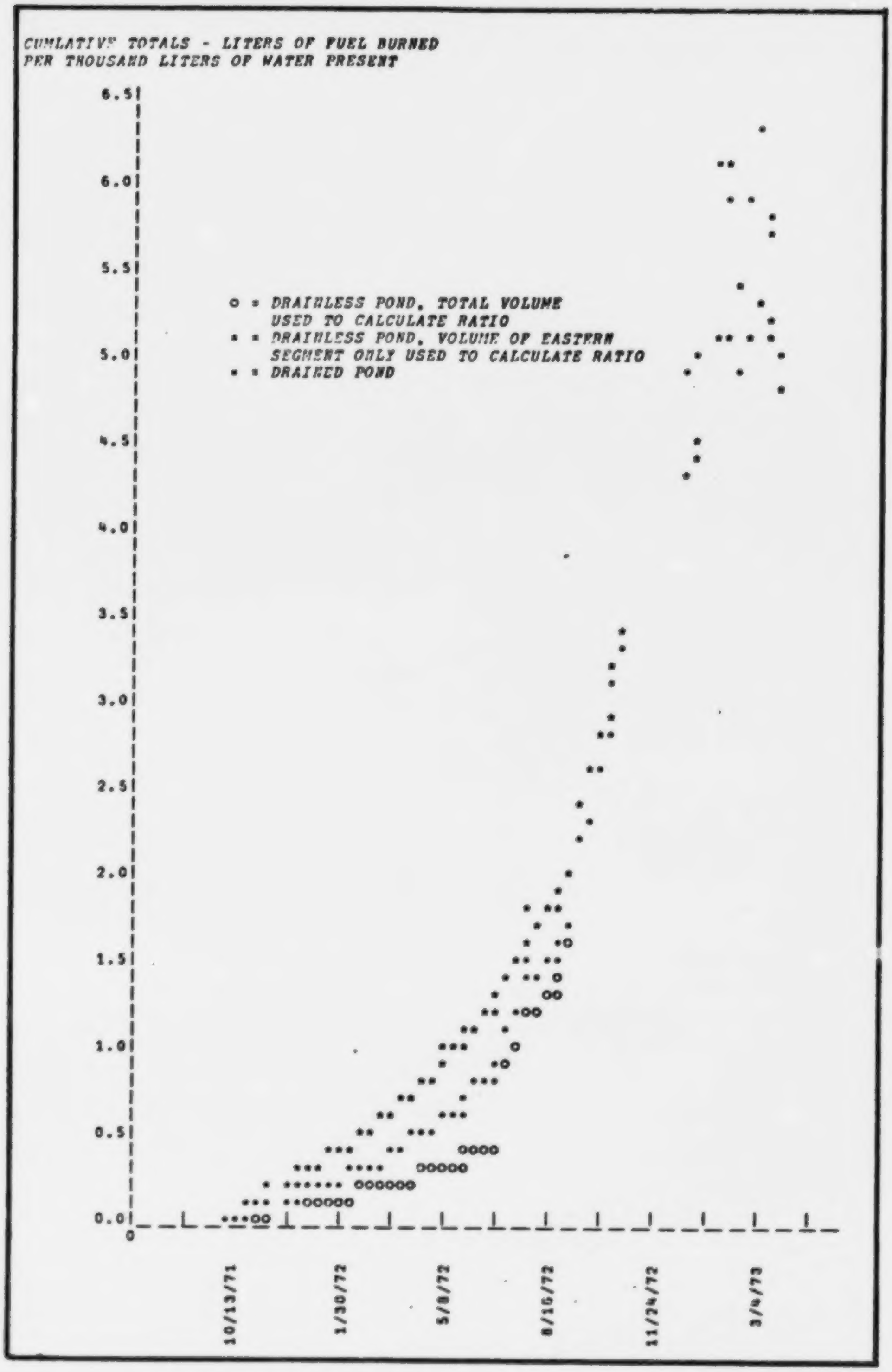

Figure B10. Cumulative volume of fuel burned (in liters) per thousand liters of pond water at any given date. Two values are given for Drainless Pond - one for the entire water volume and one for the Eastern (motor containing) pool only. Table B1 lists plotted values for entire project period.

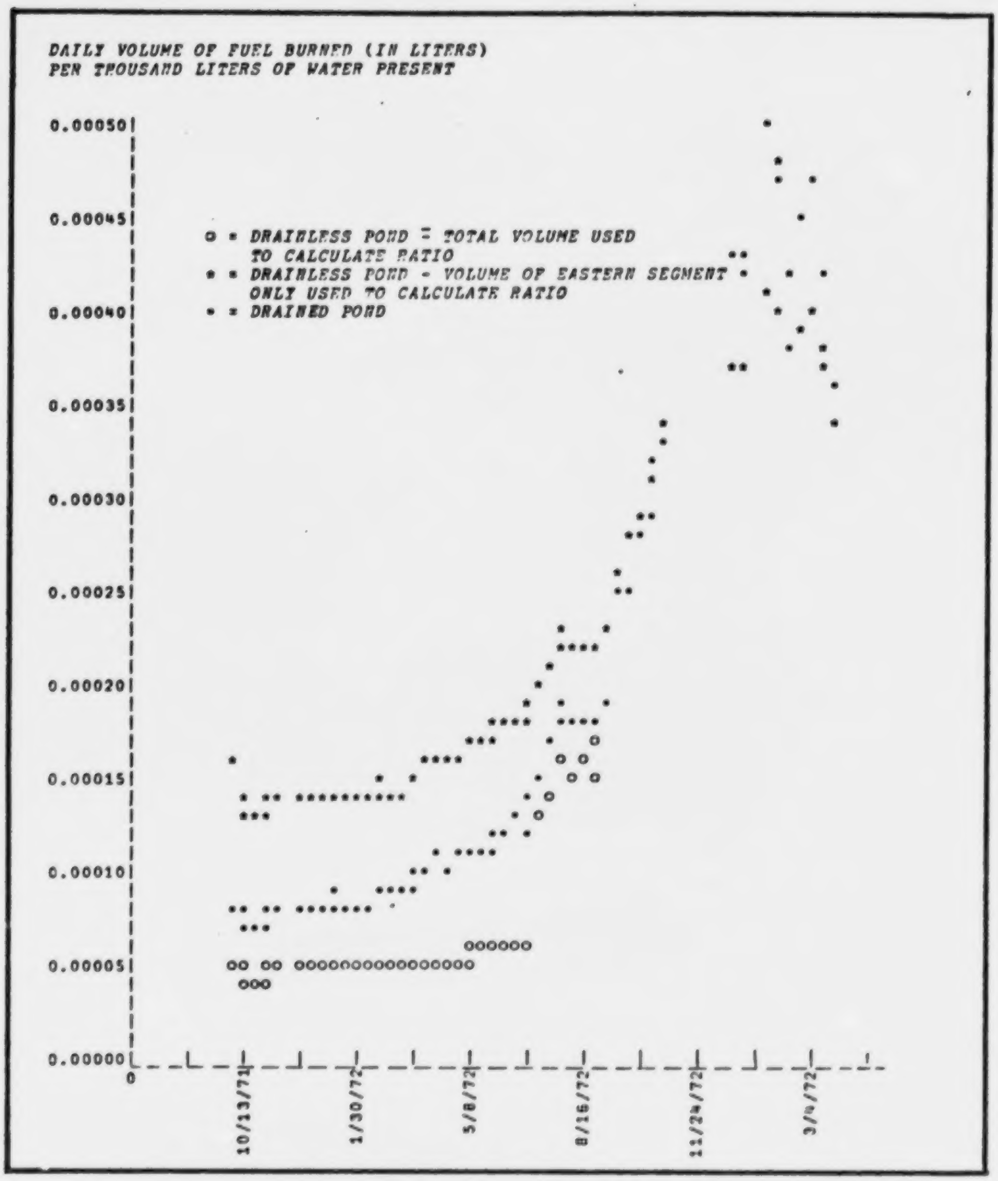

Figure B11. Daily volume of fuel burned (in liters) per thousand liters of pond water at any given date. Two values are given for Drainless Pond - one for the entire water volume and one for the Eastern (motor containing) pool only. Table B1 lists plotted values for entire project period.

Table B1. Cumulative and daily fuel consumption at the test ponds, in liters of fuel burned per 1,000 liters of water.

	CUMULATIVE FUEL BURNED (LITERS) Per 1000 Liters Water			DAILY FUEL BURNED (LITERS) Per 1000 liters water		
	DRAINLESS		DRAINED	DRAINLESS		DRAINED
DATE	TOTAL$_a$	EAST ONLY$_b$		TOTAL$_a$	EAST ONLY$_b$	
10/13/71	0.001370	0.004144	0.002011	0.000052	0.000157	0.000076
10/15/71	0.003663	0.011058	0.005778	0.000046	0.000140	0.000073
10/18/71	0.006927	0.020887	0.010995	0.000044	0.000132	0.000069
10/20/71	0.009323	0.028118	0.016236	0.000044	0.000133	0.000077
10/22/71	0.000000	0.000000	0.019780	0.000000	0.000000	0.000071
10/25/71	0.015196	0.045834	0.024847	0.000044	0.000133	0.000072
10/29/71	0.019871	0.059937	0.032465	0.000044	0.000133	0.000072
11/ 4/71	0.025922	0.078197	0.042661	0.000045	0.000135	0.000073
11/ 5/71	0.027133	0.081854	0.044908	0.000045	0.000135	0.000074
11/ 8/71	0.031153	0.094005	0.052439	0.000045	0.000137	0.000076
11/ 9/71	0.032351	0.097621	0.054797	0.000045	0.000137	0.000077
11/10/71	0.033975	0.102544	0.057496	0.000046	0.000139	0.000078
11/11/71	0.034835	0.105120	0.060818	0.000045	0.000137	0.000079
11/12/71	0.036195	0.109234	0.062053	0.000046	0.000138	0.000078
11/15/71	0.040144	0.121169	0.000000	0.000046	0.000139	0.000000
11/17/71	0.042713	0.128930	0.074435	0.000046	0.000139	0.000080
11/18/71	0.044102	0.133132	0.077142	0.000046	0.000140	0.000081
11/23/71	0.051078	0.154238	0.091312	0.000047	0.000142	0.000084
12/ 6/71	0.065736	0.198352	0.113247	0.000045	0.000137	0.000078
12/ 7/71	0.067015	0.202215	0.115515	0.000045	0.000137	0.000078
12/ 8/71	0.068211	0.205826	0.118009	0.000045	0.000137	0.000078
12/10/71	0.070737	0.213456	0.123163	0.000045	0.000137	0.000079
12/13/71	0.074381	0.224453	0.130025	0.000045	0.000137	0.000079
12/16/71	0.078127	0.235765	0.136696	0.000045	0.000137	0.000080
12/20/71	0.083144	0.250916	0.145514	0.000046	0.000138	0.000080
12/22/71	0.085125	0.256871	0.149038	0.000045	0.000137	0.000079
12/28/71	0.091800	0.276988	0.159562	0.000045	0.000136	0.000078
1/ 5/72	0.104397	0.315162	0.187644	0.000046	0.000140	0.000084
1/11/72			0.191375			0.000080
1/12/72	0.114464	0.345636	0.207136	0.000047	0.000142	0.000085
1/19/72	0.121592	0.367071	0.220702	0.000046	0.000140	0.000084
1/26/72	0.127728	0.385465	0.227354	0.000046	0.000139	0.000081
2/ 2/72	0.131307	0.396200	0.235934	0.000045	0.000136	0.000081
2/ 9/72	0.143699	0.433811	0.256287	0.000046	0.000140	0.000084
2/16/72	0.154781	0.467406	0.264415	0.000047	0.000143	0.000087
2/23/72	0.168467	0.509017	0.311997	0.000049	0.000147	0.000090
3/ 1/72	0.176481	0.533031	0.327157	0.000048	0.000144	0.000088
3/ 8/72	0.182894	0.552267	0.337169	0.000047	0.000142	0.000087
3/15/72	0.196722	0.594314	0.366775	0.000048	0.000146	0.000090
3/22/72	0.213507	0.645489	0.406859	0.000050	0.000152	0.000096
3/29/72	0.227523	0.688149	0.435632	0.000051	0.000155	0.000098
4/ 5/72	0.246954	0.747550	0.484043	0.000054	0.000163	0.000105
4/12/72	0.247761	0.749519	0.533392	0.000052	0.000157	0.000112
4/19/72	0.264927	0.801930	0.517195	0.000053	0.000161	0.000104
4/26/72	0.276758	0.837771	0.542462	0.000054	0.000163	0.000105
5/ 3/72	0.294081	0.889804	0.584355	0.000055	0.000166	0.000109
5/10/72	0.319674	0.966141	0.584190	0.000058	0.000174	0.000105
5/17/72	0.330330	0.998346	0.603663	0.000058	0.000174	0.000105
5/24/72	0.346007	1.045364	0.717091	0.000058	0.000177	0.000121
5/31/72	0.351641	1.062755	0.642609	0.000058	0.000174	0.000105
6/ 7/72	0.371559	1.122164	0.776475	0.000059	0.000179	0.000124
6/16/72	0.391520	1.182016	0.830263	0.000060	0.000182	0.000128
6/23/72	0.396643	1.197921	0.828895	0.000059	0.000179	0.000124
6/30/72	0.433535	1.307331	0.939862	0.000063	0.000190	0.000137
7/ 7/72	0.902364	1.435628	1.080441	0.000127	0.000203	0.000153
7/14/72	1.029204	1.534263	1.213566	0.000142	0.000211	0.000167
7/24/72	1.175923	1.647015	1.358590	0.000156	0.000219	0.000180
7/31/72	1.458941	1.796898	1.491401	0.000189	0.000233	0.000193
8/ 7/72	1.208913	1.715629	1.400427	0.000153	0.000217	0.000177
8/14/72	1.316529	1.794082	1.471781	0.000163	0.000222	0.000182
8/21/72	1.278353	1.802370	1.472430	0.000155	0.000218	0.000178
8/28/72	1.406825	1.889901	1.553048	0.000166	0.000224	0.000184
9/ 4/72	1.608855	1.998502	1.657165	0.000187	0.000232	0.000192
9/13/72						
9/20/72	2.389226	2.389226	2.220705	0.000264	0.000264	0.000246
9/26/72	2.598915	2.598915	2.259665	0.000283	0.000283	0.000246
10/ 4/72	2.761410	2.761410	2.607000	0.000293	0.000293	0.000276
10/11/72	2.941713	2.941713	2.820342	0.000306	0.000306	0.000293
10/18/72	3.151398	3.151398	3.094944	0.000322	0.000322	0.000316
10/25/72	3.354383	3.354383	3.277535	0.000336	0.000336	0.000328
12/22/72	4.319608	4.319608	4.930934	0.000375	0.000375	0.000428
12/29/72	4.388960	4.388960	5.010101	0.000375	0.000375	0.000428
1/ 5/73	4.458311	4.458311	5.025541	0.000375	0.000375	0.000423
1/12/73						
1/19/73	5.079114	5.079114	6.119068	0.000414	0.000414	0.000499
1/24/73	5.090781	5.090781	6.147072	0.000411	0.000411	0.000496
2/ 2/73	5.070835	5.070835	5.865940	0.000404	0.000404	0.000467
2/ 9/73	6.066456	6.066456	5.938658	0.000476	0.000476	0.000466
2/16/73	5.398441	5.398441	4.907986	0.000418	0.000418	0.000380
2/23/73	5.125865	5.125865	5.887131	0.000391	0.000391	0.000449
3/ 2/73	5.292613	5.292613	6.285090	0.000396	0.000396	0.000470
3/12/73	5.112197	5.112197	5.691356	0.000375	0.000375	0.000417
3/16/73	5.173341	5.173341	5.771160	0.000377	0.000377	0.000420
3/26/73	4.829154	4.829154	5.036126	0.000345	0.000345	0.000360

[a] Calculated using the volume of the entire pond, inclûding the spillover pond.

[b] Calculated using the eastern pond segment only: see text: actual treatment levels

APPENDIX C

SELECTION OF TREATMENT LEVELS

The first consideration was to ascertain the number of boats that could reasonably be expected to occupy a given surface areas of water, and the amount of fuel consumed by these boats in their activities. Data reported by Threinen (51) for Lake Geneva, Wisconsin, was employed to estimate fuel use per unit area. He defined Lake Geneva in terms of spatial requirements, proximity to highly populated areas, and the optimum capacity for motorboating (which he contends to be 10 acres per boat).

Schematic flow sheets of the instantaneous boat population and specific boating activities for Lake Geneva, Wisconsin, are shown in Figures C1 and C2. By using these data and assuming various lake depths, fuel use per unit volume can be calculated for the test lakes. These calculations are based on the assumptions listed below:

ASSUMPTIONS

1. Water skiing requires a 40 hp engine;
2. Speed boating requires 10 hp;
3. Trolling requires 5 hp;
4. Fishing boat requires 0 hp;
5. One pound of fuel is consumed per hp per hour;
6. One gallon of fuel weighs approximately 6 pounds;
7. One half peak boating activity five days per week;
8. Peak boating activity two days per week; and
9. Twelve month boating season.

CALCULATIONS (Use rates are taken from Figures C1 and C2)

1. An estimate was made of the total peak daily horsepower requirements of boats using Lake Geneva, Wisconsin, as follows:
   a. For the 8 hour period from 1000 hrs to 1800 hrs
      (1) 150 boats water skiing require 8 hrs x 40 hp/boat x 150 boats = 48,000 hp hours
      (2) 150 boats cruising require 8 hrs x 10 hp/boat x 150 boats = 12,000 hp hrs
      (3) 300 boats non-mobile require 0 hp hrs
      (4) Total requirements are 60,000 hp hrs
   b. From 0600 hrs to 1000 hrs and 1800 hrs to 2000 hrs, a total of 6 hrs
      (1) 540 boats non-mobile = 0 hp hrs
      (2) 60 boats trolling 6 hrs x 5 hp/boat x 60 boats = 1800 hp hrs
      (3) Total requirements are 1800 hp hrs
   c. The total peak daily horsepower requirement therefore, equals Total (a) + Total (b) = 61,800 hp hrs

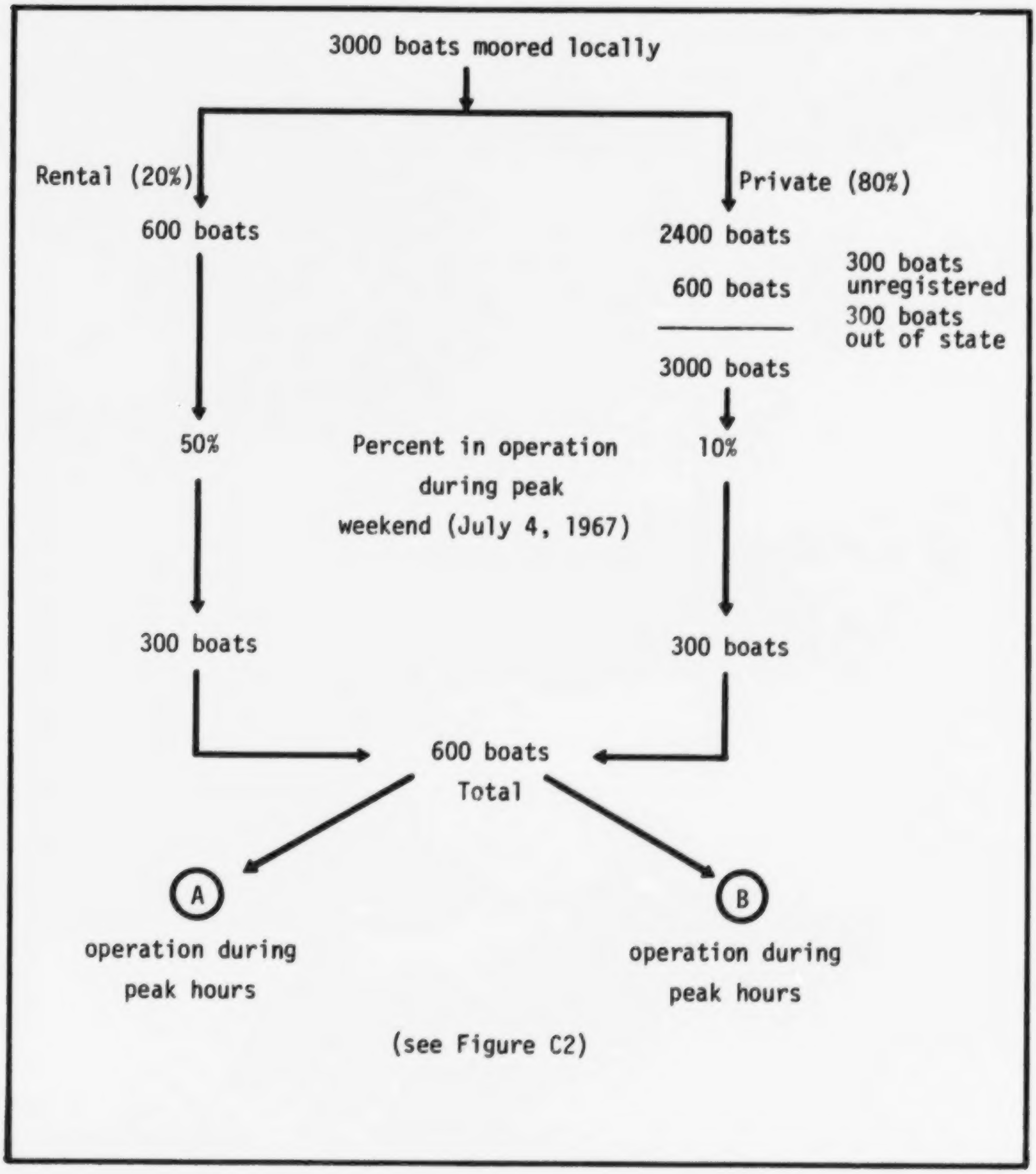
3000 boats moored locally
Rental (20%)
Private (80%)
600 boats
2400 boats
600 boats
300 boats unregistered
300 boats out of state
3000 boats
50%
Percent in operation during peak weekend (July 4, 1967)
10%
300 boats
300 boats
600 boats Total
A
B
operation during peak hours
operation during peak hours
(see Figure C2)

Figure C1. Boating operation during a period of maximum utilization, Lake Geneva, Wisconsin (51).

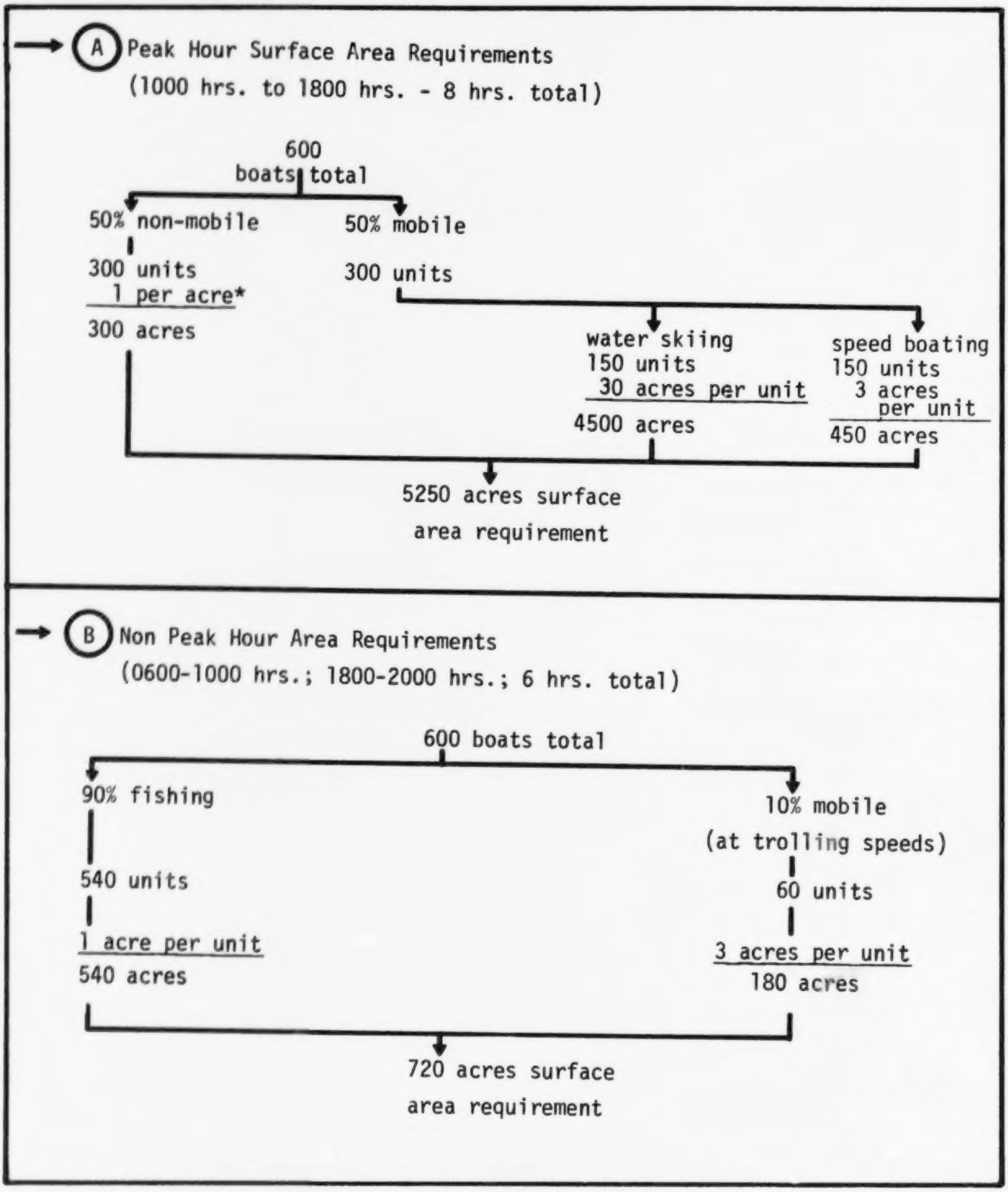
A
Peak Hour Surface Area Requirements
(1000 hrs. to 1800 hrs. - 8 hrs. total)
600 boats total
50% non-mobile
50% mobile
300 units
1 per acre*
300 acres
300 units
water skiing
150 units
30 acres per unit
4500 acres
speed boating
150 units
3 acres per unit
450 acres
5250 acres surface area requirement
B
Non Peak Hour Area Requirements
(0600-1000 hrs.; 1800-2000 hrs.; 6 hrs. total)
600 boats total
90% fishing
540 units
1 acre per unit
540 acres
10% mobile
(at trolling speeds)
60 units
3 acres per unit
180 acres
720 acres surface area requirement

Figure C2. Surface area requirements for boating activity during a peak weekend on Lake Geneva, Wisconsin (51).

2. The weekly horsepower requirement is calculated on the basis of peak use 2 days per week and 1/2 use 5 days per week = 2 x 61,800 hp hrs + 1/2 x 5 x 61,800 hp hrs = 278,100 hp hrs per week.
3. Horsepower hours per unit surface area per week is computed. The surface area of Lake Geneva is 5,100 acres, therefore:

   hp hrs/acre per week = 278,100 hp hrs/week divided by 5,100 acres = 55 hp per week.
4. Next the yearly horsepower hour requirement per acre is calculated and this figure is converted to fuel use per acre per year.
   a. 55 hp hrs/acre per week x 52 weeks per year = 2860 hp hrs/acre per year.
   b. 2860 hp hrs/acre per year x 1 lb fuel/hp hr = 2860 lbs fuel/acre per year.
   c. 2860 lbs fuel/acre per year x 1/6 gallon fuel/lb = 477 gallons fuel/acre per year.
5. Assume that the average depth of Lake Geneva = 12 feet and calculate the fuel volume to water volume ration per year:

   477 gal fuel/acre per year = 477 gal fuel/12 acre ft. per year = 477 gal fuel/3.91 x 10^6 gal water/yr = 1.22 x 10^{-4} gal fuel/gal water/yr.
6. It was desired to simulate a level of motor operation at 3 times the normal optimum use rate. Therefore:
   a. 3 x normal = 3 x 1.22 x 10^{-4} gal fuel/gal water per year = 3.66 x 10^{-4} gal fuel/gal water per year.
   b. Drained Engine Pond contained at the time of its survey approximately 3,207,000 gals of water. It therefore required 3.66 x 10^{-4} x 3.207 x 10^6 = 1174 gal fuel/yr.
   c. Drainless Engine Pond contained at the time of survey approximately 3,293,000 gals of water. It therefore required 3.66 x 10^{-4} x 3,293 x 10^6 = 1205 gal fuel/yr.
7. The average weekly fuel requirement is calculated as:

   1200 gals fuel/yr x 1/52 = 23 gals fuel/wk. The test motors will only be run 5 days per week, so 23 gals fuel/week x 1/5 - 4.6 gals/day.

APPENDIX D

ENGINE DRAINAGE TESTS

Outboard engines are generally of two stroke design (often called two cycle engines) and use crankcase pressurization to move the fuel-air mixture from the carburetor and manifold to the cylinder. In order to lubricate the moving parts in the crankcase, oil is mixed with fuel and is deposited along with the fuel on these parts as the fuel-air mixture moves through the crankcase. Because it is more volatile, the fuel re-vaporized leaving a mixture consisting of oil and a small quantity of fuel on the wearing surfaces. The oil tends to build up and subsequently drip to the lowest point of the crankcase. On very old engines no means was provided for removal of the oil; it simply reached a level where it was drawn into the cylinder and burned. This tended to foul plugs quickly and cause rough operation. During the 1930's, it was found that the drainage could be eliminated by passing it through a one-way valve into the exhaust stream. Until recently, the majority of engines manufactured used this method for removal of oil from the crankcase.

Recently, almost all engines designed have utilized a new recycling system in which the drainage is routed back into the crankcase for reuse.

Inasmuch as many of the older drained engines remain in usage, this study compared the effects of drained vs. drainless engines in separate test ponds in addition to assessing the overall effects of outboards on ponds. Subsequently, the drained engines were tested to determine the quantity of drainage discharged under various operating conditions.

METHODS

Test wheels were used on the engines to ensure that engine loading under static testing conditions would be similar to actual boating use. To allow for accurate measurements, fuel was provided to the engines from a 50 ml burette connected by a short hose. Care was taken to insure that no air bubbles remained in the hose. The burrette was filled, the engine speed set, and the test begun as the fuel passed the 50 ml mark. A stopwatch was started and the drainage tube was inserted in a small graduate used for collection of the drainage. The test was stopped after fuel inputs of 20 ml and 50 ml. The drainage was then measured and recorded, and the graduate was dried prior to the next test. Of the total number of tests performed at this time (120), about one-half used 50 ml of fuel and the other half used 20 ml of fuel.

The engine running speeds were set using an electronic tachometer.

Idle speeds were determined as the lowest speed at which the engine would operate smoothly (800 RPM).

RESULTS

The engines used during the first tests were an OMC 6 hp, a Mercury 9.8 hp, and a Chrysler 9.9 hp. Part of the testing was conducted in a test tank, while the other testing was conducted at the test lakes with the engines mounted on docks. In all, 40 tests were performed on the Chrysler, 30 on the OMC, and 48 on the Mercury. Results are presented in Tables D1, D2, and D3.

Tests on the Mercury 9.8 hp (Table D1) show a consistently decreasing trend of percent fuel drained as the RPM level is increased. The percentage of drainage discharged is highest at the idle setting (800 RPM). Table D2 indicates that for the Johnson 6 hp, the percentage of fuel drained is highest between 1500-2500 RPM. The average values are much lower for the Johnson, ranging from 1.0 percent to 5.0 percent, as compared to a range of 3.0 percent to 11.3 percent for the Mercury. From Table D3 it can be seen that the general trend for percentage of fuel drained for the Chrysler 9.9 hp is a similar to that of the Johnson (high values occurring between 2000-3000 RPM), but the range of the average values is very much like that of the Mercury (3.5 percent to 11.4 percent).

In July, 1972, the small engines were retested for drainage. During this second test, drainage was collected in a venter flask immersed in an ice bath, and 5.4 gallons of fuel were burned for each test. The engines had been run approximately 1300 hours prior to testing. The results of this second series of testing are presented in Table D4.

The general trend of the results in Table D4 for the Mercury 9.8 hp is consistent with that shown in Table D1, namely, the higher levels of drainage occurs at the lower RPM levels. The actual percentage values, however, are significantly lower than those of Table D1. Results of the testing on the Johnson 6 hp and the Chrysler 9.9 hp indicate that both the general trend and the actual percentage values are similar to those results given in Tables D2 and D3, respectively.

In the third series of testing, an 18 hp OMC and a 35 hp Chrysler were used. These were run for one hour or one gallon of fuel usage, whichever came first. Similar to the second series of testing, drainage was collected in a flask which was immersed in an ice bath. Results of these tests are presented in Table D5. Both engines had been operated approximately 300 hours prior to testing.

Table D1. Results of drainage tests on a Mercury 9.8 hp engine showing percentage of fuel drained at various operating levels for 20 or 50 ml of fuel, and for 1000 ml of fuel.

Engine Speed (RPM)	Idle (800)	1000	1500	2000	2500	3000	4000
% Fuel Drained	11.0	10.0	9.5	8.5	7.5	6.0	3.0
	9.5	9.0	8.0	7.5	7.5	5.5	3.5
	9.0	8.5	8.5	8.0	7.5	5.5	3.0
	10.0	10.0	9.5	8.5	8.0	5.5	3.5
	10.0	9.0	9.0	8.5	6.0	4.0	3.5
	15.0	14.0	13.5	9.5	8.0	6.5	1.5
	9.0	10.0	9.5	8.5	7.0	5.5	
Average (using 20 or 50 ml. of fuel)	10.5	10.1	9.6	8.4	7.4	5.5	3.0
Tests using 1000 ml. of fuel:							
Average	11.3	10.1		3.4		3.7	

Table D2. Results of drainage tests on a Johnson 6 hp engine showing percentage of fuel drained at various operating levels for 20 or 50 ml of fuel.

Engine Speed (RPM)	Idle (800)	1000	1500	2000	2500	3000	3300	4000
% Fuel Drained	0.5	0.2	4.4	5.4	4.4	4.5	2.5	2.2
	0.2	4.0	5.5	4.4		6.5	2.4	2.5
	1.7	4.5		4.5		4.6	2.2	2.2
	1.6	1.9		4.7		2.2		2.2
		0.4				2.9		
		0.2				1.0		
Average	1.0	1.9	5.0	4.8	4.4	3.6	2.4	2.3

Table D3. Results of drainage tests on a Chrysler 9.9 hp engine showing percentage of fuel drained at various operating levels for 20 or 50 ml of fuel, and for 1000 ml of fuel.

Engine Speed (RPM)	Idle (800)	1000	1500	2000	2500	3000	4000
% Fuel Drained	5.5	7.0	5.0	6.5	14.0	12.5	9.0
	6.0	7.5	5.5	7.0	9.0	12.5	11.5
	2.3	2.7	7.2	14.3	14.4	6.3	6.2
	0.8	1.6	2.4	7.6	8.1	6.0	6.7
	1.6	1.7		6.8		5.0	4.4
	1.5	9.4		11.0		11.4	7.4
	6.8			8.6			
Average (Using 20 or 50 ml. fuel)	3.5	5.0	5.0	8.8	11.4	9.0	7.5
Test using 1000 ml. fuel:							
Average	9.7	8.7		11.0		8.4	

Table D4. Drainage rates of four small outboard engines as a function of engine speed and running time.

Engine	Approximate RPM	Running Time-Hours	ml Fuel	ml Drainage	Percent Fuel Drained
MERC 9.8 (#3264683)	3500	10	20,440	707	3.46
	1200	13	20,440	1,150	5.63
MERC 9.8 (#3263846)	3500	10	20,440	273	1.33
	1250	10	20,440	1,287	6.30
	3500	9	20,440	566	2.77
OMC 6 (#6R-72D)	1300	25	20,440	150	0.73
	3400	12	20,440	430	2.10
CHRY 9.9	1300	10	20,440	980	4.79
	3400	6	20,440	1,720	8.42

It can be seen from Table D5 that there is a change in trend for both the OMC (Johnson) and Chrysler engines. The OMC 18 hp had a higher percent of fuel drained at the low RPM level than at the higher level (2.44% and 3.12% at 1200 RPM, and 0.58% at 3300 RPM). The Chrysler 35 hp engine exhibited a similar trend with a percent of fuel drained being 14.31% at 1300 RPM and 0.71% at 3300 RPM.

Similar testing has been performed by other individuals and groups. Some of the data developed are presented in Tables D6, D7, and D8.

DISCUSSION

It can be concluded from this study that the percentage of fuel drained (fuel loss) during outboard engine operation is dependent on three major factors. They are:

1. The operating speed (RPM);
2. The manufacturer (OMC, Mercury, or Chrysler); and
3. The size of the engine (hp).

The Mercury 9.8 hp was found to have the highest drainage rate at the slower operating speed, and in general, the percent of fuel drained was higher than the 6 hp Johnson, and consistent with that of the 9.9 hp Chrysler. Both the 6 hp Johnson and the 9.9 hp Chrysler had the highest percent of fuel drainage in the mid-range of operating speeds. The data assembled on the larger Johnson and Chrysler engines was limited. However, it was observed that the highest percent of fuel drainage occurred at the lowest operation speed.

Generally speaking, drainage rates are less than those found by other investigations under similar conditions. The reason might be partially due to the age of the engines, although the engines tested in this study were probably operated more extensively. The outboard motors used in this study were 1971 OMC, Chrysler, and Mercury models. Some other possible causes for the lower observed drainage rates are presented as follows:

1. Engine Variables
    a. Operating temperature - a higher temperature would result in less fuel waste;
    b. Tuning-testing the engines at a constant speed tends to foul spark plugs and other engine components, thereby increasing fuel waste;
    c. Age - parts in older engines tend to be worn, increasing fuel waste;
    d. Usage - engines that receive little usage tend to operate less efficiently; and
    e. Load - a heavily loaded engine has to work harder to complete a given job. This increases engine temperature and fuel consumption.

Table D5. Drainage rates of OMC 18 hp and a Chrysler 35 hp outboard engines as a function of engine speed and running time.

Engine	Approximate RPM	Running Time-Hours	ml Fuel	ml Drains	Percent Fuel Drained
OMC 18 hp.	1200	60	2,745	67	2.44
	1200	60	2,945	92	3.12
	3300	39	3,785	22	0.58
CHRY 35 hp.	1300	60	3,565	510	14.31
	3300	36	3,738	27	0.71

Table D6. Percent of original fuel found in outboard motor exhaust.

	Percent of Fuel Unburned	
Investigator	Range	Average
Parker (33)	up to 56	
Snell (43)	10 -- 33	
Muratori (30)	up to 40	10 to 20
Shuster (42)	4 -- 30	
Ferren (14)	1 -- 55	27 (mean)

Table D7. Percent of fuel waste for various age and horsepower outboard motors.

Regular Crankcase[a]			Smaller Crankcase[b]		
Year	HP	Fuel Waste Percentage	Year	HP	Fuel Waste Percentage
1963	5	1.57	1967	95	2.34
1965	33	31.25	1966	50	1.56
1964	60	54.70	1959	40	1.56
1959	50	53.10	1968	125	2.00
1961	40	31.25			

[a] All motors operated at 1500 rpm ± 100 rpm.

[b] All motors operated at 600 rpm ± 100 rpm.

Table D8. Percent unused fuel vs. engine spped of operation.

Engine Speed (RPM)	Percent Unused Fuel			
	9.2 HP Motor[a] from Ferren	50 HP Motor[a] from Ferren	Untuned 1968-33 HP Motor[b]	Tuned 1968 33 HP Motor[b]
800	20	14	--	--
1000	19	25	30.51	26.06
1250	21	15	--	--
1500	--	14	--	--
2000	18	--	7.11	6.00
2500	14	--	7.45	--
3000	9	0.5	--	2.97
4000	5	--	--	--
4800	3	--	--	--
5000	--	0.5	--	--

[a] Outboard motors were 1965 models (14).

[b] Test conducted by Shuster for the Environmental Protection Agency(42).

2. Testing Variables

   a. Test tank size - the engines in this study were tested in 55 gallon drums. Smaller drums might result in higher operating temperature;
   b. Collection vessel dimensions - more volatiles are likely to be trapped in tall, narrow containers than short, wider vessels;
   c. Ambient air temperature - lower temperatures might tend to lower operating temperatures; and
   d. Lenght of test - longer test periods might tend to increase operating temperatures. However, some fuel evaporation occurred from collection vessels in those test which lasted for long periods of time. The 6 hp Johnson, for example, ran for about 25 hours on 5.4 gallons of fuel.

Production of drained engines ceased in 1972. It is estimated that approximately seven million of these remain in operation. An extensive study of engine drainage is presently underway at Southwest Research, Inc.

APPENDIX E

LIST OF MACROINVERTEBRATES COLLECTED

Table E1. Summary of macroinvertebrates collected in Drained Engine Pond on August 18, 1971.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	701	372	1816	57	243
Chrysops sp.		29	29		
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	415	415	1001	86	86
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.					
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus					
Ablabesmyia peleensis					
Ablabesmyia rhamphe					
Ablabesmyia ornata					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paraponyx sp.					
Hirudinea					
Pisciolidae sp.			14		
Hellobdella stagnalis				43	
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.				14	
Phagocata sp.					
Hydracarina					
sp. x		57			29
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.				14	
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca		43	57	140	29
Oligochaeta					
Tubificidae sp. x	29	72	14	129	
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp h					
Density of organisms per station	1145	988	2931	483	387

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Table E2. Summary of macroinvertebrates collected in Drainless Engine Poind on August 18, 1971.

Taxa	Population Density (#/m²)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	372	143	72	458	
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	186	72	157	114	
Tanytarsus sp.*					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.					
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Coleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.		29			
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Triciadida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celithemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca		29	14		
Oligochaeta					
Tubificidae sp. x	43	14	57	114	
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	601	287	300	686	

Table E3. Summary of macroinvertebrates collected in Control Pond on August 18, 1971.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	400	372	458	615	358
Chrysops sp.	14	14			14
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	400	215	829	400	400
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.					
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus					
Ablabesmyia peleensis					
Ablabesmyia rhamphe					
Ablabesmyia ornata					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.	43			14	
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.			29	14	
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.		14			
Gomphus cavillaris	43				
Enallagma sp.				14	
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyalella azteca	272	57	358	400	43
Oligochaeta					
Tubificidae sp. x		72	57		243
Tubificidae sp y		14			
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	1172	758	1731	1457	1058

Table E4. Summary of macroinvertebrates collected in Drainless Engine Pond on October 19, 1971

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis		229	29	558	
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	186	129	14	315	
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.					
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus					
Ablabesmyia peleensis					
Ablabesmyia rhamphe					
Ablabesmyia ornata					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.					
Lestes sp.	29	14	14	29	
Pachydiplax longipennis					
Tetragoneuria sp.			29		
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca					
Oligochaeta					
Tubificidae sp. x	458	129	29	308	
Tubificidae sp y	29	14	45		
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	702	515	160	1210	

Table E5. Summary of macroinvertebrates collected in Control Pond on October 19, 1971.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	29		43	129	386
Chrysops sp.			14		
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					29
Chironomidae sp.	57	14	114	372	344
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.					
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus					
Ablabesmyia peleensis					
Ablabesmyia rhamphe					
Ablabesmyia ornata					
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei	14				
Illinobdella alba					
Glossiphonia sp.					
Hydracarina					
sp. x					
Cladocera					29
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura	14			14	14
Libellulidae	14				
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.	27			14	29
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca	358		237	86	200
Oligochaeta					
Tubificidae sp. x	29	57	57		
Tubificidae sp y	29		29		
Limnodrillis sp.					
Oligochaeta sp b					
Trichoptera					
sp. x					14
Psychomyiidae sp.					
Polycentropus sp.					
Density of organisms per station	571	71	494	615	1045

Table E6. Summary of macroinvertebrates collected in Drained Engine Pond on October 19, 1971.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	930	372	658	972	5001
Chrysops sp.	29				
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	100	200	243		172
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.					
Microtendipes sp.					
Clinotanypus sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.					
Coeleoptera					
Berosus sp.		14			
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.			14		
Orthemis ferruginea		14			
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca		14	157		14
Oligochaeta					
Tubificidae sp. x		14	86		51
Tubificidae sp y			14		
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	1059	628	1172	972	5238

Table E7. Summary of macroinvertebrates collected in Drainless Engine Pond on February 7, 1972.

Taxa	Population Density (#/m²)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	29	143	72	29	
Chrysops sp.		14			
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	86	1044	1559	801	
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x			14	43	
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Amphipoda					
Hyallela azteca				43	
Oligochaeta					
Tubificidae sp. x	86	14	57	14	
Tubificidae sp y	14				
Limnodriilis sp.					
Oligochaeta sp b					
Density of organisms per station	215	1215	1702	930	

Table E8. Summary of macroinvertebrates collected in Drained Engine Pond on February 7, 1971.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	100	501	86	215	1031
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	1031	472	200	400	172
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Ephemeroptera					
Ephemerella sp.					
Caenis sp.					
Nematoda					
Rhabditina sp.	43				
Trichoptera					
sp. x					14
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Pisciolidae sp.				14	
Hellobdella stagnalis					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca				143	
Oligochaeta					
Tubificidae sp. x	43	14	43	43	
Tubificidae sp y		14		14	
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	1217	1001	329	829	1217

Table E9. Summary of macroinvertebrates collected in Control Pond on February 7, 1972

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	200	243	286	29	186
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	72	229	400	400	286
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.					
Microtendipes sp.					
Clinotanypus sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.		14			43
Hirudinea					
Piscicolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.		14	29		43
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.			14		
Erythemis sp.		29			14
Nannothemis bella					
Anomalagrion hastatum		29			
Celithemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyalella azteca		72	257	358	286
Oligochaeta					
Tubificidae sp. x	14	14	143	86	200
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	286	644	1129	873	1058

Table E10. Summary of macroinvertebrates collected in Drainless Engine Pond on March 8, 1972.

Taxa	Population Density (#/m^2)			
	Station 1	Station 2	Station 3	Station 4
Diptera				
Chaoborus punctipennis	86	129	43	86
Chrysops sp.				
Bezzia sp.				
Palpomyia sp.				
Dasyhelia sp.				
Chironomidae sp.	129	272	429	224
Tanytarsus sp.				
Lepidoptera				
Paradonyx sp.			14	
Hirudinea				
Pisciolidae sp.				
Hellobdella stagnalis				
Illinobdella sp.				
Hellobdella sp.				
Illinobdella moorei				
Illinobdella alba				
Glossiphonia sp.				
Turbellaria				
Tricledida sp.				
Phagocata sp.				
Hydracarina				
sp. x				
Cladocera				
Daphnia sp.				
Odonata				
Coenagrionidae sp.				
Orthemis ferruginea				
Argia sp.				
Ischnura				
Libellulidae				
Dythemis sp.				
Erythemis sp.				
Nannothemis bella				
Anomalagrion hastatum				
Celethemis sp.				
Lestes sp.				
Pachydiplax longipennis		14		
Tetragoneuria sp.				
Gomphus cavillaris				
Enallagma sp.				
Amphiagrion saucium				
Tramea carolina				
Amphipoda				
Hyallela azteca	29	215	100	
Oligochaeta				
Tubificidae sp. x	14		114	172
Tubificidae sp y				
Limnodrillis sp.				
Oligochaeta sp b				
Density of organisms per station	258	630	700	482

Table E11. Summary of macroinvertebrates collected in Drained Engine Pond on March 8, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	114	286	243	100	406
Chrysops sp.		14			
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.	286	172	215	86	57
Tanytarsus sp.					
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.		29	14		
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.		14			
Lestes sp.			14		
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca		29	86	272	
Oligochaeta					
Tubificidae sp. x	14	43	143	43	14
Tubificidae sp y					
Limnodrillus sp.					
Oligochaeta sp b					
Density of organisms per station	414	587	715	501	477

Table E12. Summary of macroinvertebrates collected in Control Pond on March 8, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	29	114	172	72	186
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.	14			29	
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.		29	57		14
Procladius sp.	29	14	114	200	29
Microtendipes sp.		29			
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x		29			
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paraponyx sp.		29			
Hirudinea					
Piscicolidae sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.	14		14		100
Nannothemis bella					
Anomalagrion hastatum					
Celithemis sp.	14				
Lestes sp.	14				
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyalella azteca		86	14	200	143
Oligochaeta					
Tubificidae sp. x					
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	114	330	371	501	472

Table E13. Summary of macroinvertebrates collected in Drainless Engine Pond on April 3, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis			14		
Chrysops sp.			14		
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.	72	129		157	
Microtendipes sp.		14		29	
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus					
Ablabesmyia peleensis					
Ablabesmyia rhamphe					
Ablabesmyia ornata					
Ablabesmyia janta					
Ablabesmyia sp.					
Harnischia collator					
Nilotanypus sp.					
Chironomus (Tribelos) sp.					
Larsia berneri	14		14		
Larsia lurida					
Chironomus (Limnochironomus) tenuicaudatus					
Coelotanypus concinnus					
Tanypus punctipennis					
Apsectrotanypus					
Diamesa sp.					
Polypedilum fallax					
Polypedilum sp.					
Glyptotendipes					
Conchapelopia sp.					
Chironomus (Dicrotendipes) nervosus					
Chironomus (Einfeldia) brunneipennis					
Dicrotendipes modestus		14			
Pentaneurini sp.		14		29	
Ephemeroptera					
Ephemerella sp.					
Caenis sp.					
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.					
Density of organisms per statior	86	171	42	215	

Table E14. Summary of macroinvertebrates collected in Drained Engine Pond on April 3, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	14	200	43		215
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.				14	
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.	57	129		57	29
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis			43		
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celithemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca		29	72		
Oligochaeta					
Tubificidae sp. x					
Tubificidae sp y					
Limnodrillis sp.			43		14
Oligochaeta sp b					
Density of organisms per station	71	358	201	71	258

Table E15. Summary of macroinvertebrates collected in Control Pond on April 3, 1972

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis		57	215	172	286
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.	29	29			
Chironomus (Chironomus) sp.					14
Chironomus (Dicrotendipes) sp.					
Procladius sp.	57	57	29	57	
Microtendipes sp.					
Ablabesmyia janta					
Ablabesmyia sp.	14				
Harnischia collator					
Nilotanypus sp.					
Chironomus (Tribelos) sp.					
Larsia berneri					
Larsia lurida					
Chironomus (Limnochironomus) tenuicaudatus					
Coelotanypus concinnus	14				
Dicrotendipes modestus				43	
Pentaneurini sp.					
Ephemeroptera					
Ephemerella sp.	14				
Caenis sp.					
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.				14	
Hirudinea					
Piscicolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.	14				
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.	14	14			
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.	14	14		14	
Lestes sp.					
Amphipoda					
Hyallela azteca	29	29		57	
Oligochaeta					
Tubificidae sp. x	29			57	29
Tubificidae sp y					
Limnodrillis sp.	14			14	29
Oligochaeta sp b					
Density of organisms per station	242	200	244	428	358

Table E16. Summary of macroinvertebrates collected in Drainless Engine Pond on May 11, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis		14	14	29	
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.		29			
Procladius sp.	14	14	57		
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus					
Ablabesmyia peleensis					
Ablabesmyia rhamphe					
Ablabesmyia ornata					
Ablabesmyia janta					
Ablabesmyia sp.	14		14		
Harnischia collator					
Nilotanypus sp.					
Chironomus (Tribelos) sp.					
Larsia berneri					
Larsia lurida				29	
Chironomus (Limnochironomus) tenuicaudatus					
Hydracarina					
sp. x					
Cladocera					
Daphnia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.					
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca			14	29	
Oligochaeta					
Tubificidae sp. x	14			29	
Tubificidae sp y				29	
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	42	57	99	145	

Table E17. Summary of macroinvertebrates collected in Drained Engine Pond on May 11, 1972

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	29	29	14	43	57
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.				29	
Procladius sp.	57	86			43
Coelotanypus concinnus					
Tanypus punctipennis		43			
Apsectrotanypus					
Diamesa sp.					
Polypedilum fallax					
Polypedilum sp.					
Glyptotendipes					
Conchapelopia sp.					
Chironomus (Dicrotendipes) nervosus					
Chironomus (Einfeldia) brunneipennis					
Dicrotendipes modestus					
Pentaneurini sp.	14				
Ephemeroptera					
Ephemerella sp.					
Caenis sp.					
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.				29	
Cyrnellus sp.				14	
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Piscicolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.	43				
Helobdella sp.	14	29			
Illinobdella moorei					
Amphipoda					
Hyallela azteca		29		29	
Oligochaeta					
Tubificidae sp. x					
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	157	216	14	144	100

Table E18. Summary of macroinvertebrates collected in Control Pond on May 11, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	57	86	100		86
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.				29	
Chironomus (Dicrotendipes) sp.	29		14		86
Procladius sp.	70	43	43	29	72
Microtendipes sp.	29			14	
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus					
Ablabesmyia paleensis					
Ablabesmyia rhamphe					
Ablabesmyia ornata					14
Chironomus (Limnochironomus) tenuicaudatus		72			
Coelotanypus concinnus					
Tanypus punctipennis	14				14
Apsectrotanypus					
Diamesa sp.					
Polypedilum fallax					
Polypedilum sp.					
Glyptotendipes					
Conchapelopia sp.				29	
Chironomus (Dicrotendipes) nervosus					
Chironomus (Einfeldia) brunneipennis					
Dicrotendipes modestus					
Pentaneurini sp.				14	
Ephemeroptera					
Ephemerella sp.				14	
Caenis sp.				43	14
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.	14				
Polycentropus sp.					
Cyrnellus sp.			29		
Leptocella sp.	29				
Phylocentropus sp.					14
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					14
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celithemis sp.	14				
Lestes sp.					
Pachydiplax longipennis	14			29	
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium		14			
Tramea carolina					
Amphipoda					
Hyallela azteca	57	57	43		143
Oligochaeta					
Tubificidae sp. x	29		29	100	86
Tubificidae sp y					
Limnodrillis sp.				29	
Oligochaeta sp b					
Density of organisms per station	356	272	258	330	543

Table E19. Summary of macroinvertebrates collected in Drainless Engine Pond on June 26, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	14	14	29	14	
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.			29		
Chironomus (Dicrotendipes) sp.				14	
Procladius sp.			14	72	
Microtendipes sp.					
Dicrotendipes modestus					
Pentaneurini sp.			29		
Ephemeroptera					
Ephemerella sp.					
Caenis sp.					
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus	14				
Oecetis sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.		14			
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis				14	
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.					
Hydracarina					
sp. x		14			
Cladocera					
Daphnia sp.					
Amphipoda					
Hyallela azteca			14		
Oligochaeta					
Tubificidae sp. x				29	
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	28	42	115	143	

Table E20. Summary of macroinvertebrates collected in Drained Engine Pond on June 26, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	14			29	200
Chrysops sp.					
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.		86	29		114
Microtendipes sp.					
Tanypus punctipennis		14			14
Apsectrotanypus					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus				29	
Oecetis sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					14
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba			14		
Glossiphonia sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Gomphus cavillaris					
Enallagma sp.					14
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca			43	14	14
Oligochaeta					
Tubificidae sp. x		14	14		
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	14	114	100	72	370

Table E21. Summary of macroinvertebrates collected in Drainless Engine Pond on August 3, 1972.

Taxa	Population Density (#/m²)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis					
Chrysops sp.					
Bezzia sp.	29		14		
Palpomyia sp.	14				
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.			29	100	
Microtendipes sp.					
Clinotanypus sp.					
Chironomus (Cryptochironomus) sp.					
Chironomus (Cryptochironomus) abortivus					
Clinotanypus thoracicus	72	100	43	172	
Diamesa sp.			14		
Ephemeroptera					
Ephemerella sp.					
Caenis sp.	14				
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.	14				
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.	43				
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.				14	
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					
Turbellaria					
Tricladida sp.					
Phagocata sp.	14				
Odonata					
Coenagrionidae sp.					
Pachydiplax longipennis	29				
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina				14	
Amphipoda					
Hyallela azteca		29	14		
Oligochaeta					
Tubificidae sp. x	86		29		
Tubificidae sp y			14		
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	315	129	157	300	

Table E22. Summary of macroinvertebrates collected in Control Pond on June 26, 1972.

Taxa	Population Density (#/m^2) Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	57		14	129	
Chrysops sp.		14			
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					14
Chironomus (Dicrotendipes) sp.	14				
Procladius sp.		29		29	29
Microtendipes sp.	72			43	
Chironomus (Einfeldia) brunneipennis				14	
Dicrotendipes modestus					
Pentaneurini sp.					
Ephemeroptera					
Ephemerella sp.					
Caenis sp.					
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus		14			72
Oecetis sp.					
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.				86	14
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.	43		14		
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca		29	43		
Oligochaeta					
Tubificidae sp. x	29		29	72	
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	215	86	100	373	129

le E23. Summary of macroinvertebrates collected in Drained Engine Pond on August 3, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	57	215	29	86	429
Chrysops sp.	29				
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.	172	172	100	129	
Microtendipes sp.	43				29
Clinotanypus sp.	14	29			14
Diamesa sp.					
Polypedilum fallax					
Polypedilum sp.					29
Glyptotendipes					
Conchapelopia sp.					
Chironomus (Dicrotendipes) nervosus					
Chironomus (Einfeldia) brunneipennis					
Dicrotendipes modestus					
Pentaneurini sp.					
Ephemeroptera					
Ephemerella sp.					
Caenis sp.		14			
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.					
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.	14			14	
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei			14		14
Illinobdella alba					
Odonata					
Coenagrionidae sp.					
Lestes sp.	14				14
Pachydiplax longipennis		14		14	
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca	72	29	57	143	215
Oligochaeta					
Tubificidae sp. x	14	29	43	57	72
Tubificidae sp y	29			14	
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	458	502	243	457	816

Table E24. Summary of macroinvertebrates collected in Control Pond on August 3, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis		72	157	57	29
Chrysops sp.	14				14
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.	215	114	129	100	57
Microtendipes sp.			86		
Clinotanypus sp.			129	14	
Chironomus (Cryptochironomus) sp.					
Polypedilum sp.			86		
Glyptotendipes					
Conchapelopia sp.					
Chironomus (Dicrotendipes) nervosus					
Chironomus (Einfeldia) brunneipennis	43	114	129	43	57
Dicrotendipes modestus					
Pentaneurini sp.					
Ephemeroptera					
Ephemerella sp.					
Caenis sp.		29		57	43
Trichoptera					
Oecetis sp.	14	14	29	43	43
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					14
Nannothemis bella					
Ancmalagrion hastatum					
Celethemis sp.					
Lestes sp.		14			
Pachydiplax longipennis		14	14	43	29
Tetragoneuria sp.					
Gomphus cavillaris	14				
Enallagma sp.				14	
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca	114	86		272	129
Oligochaeta					
Tubificidae sp. x		29	57	29	
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	414	486	816	672	415

Table E25. Summary of macroinvertebrates collected in Drainless Engine Pond on September 14, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	14	243	57	14	
Chrysops sp.	14			29	
Bezzia sp.				43	
Palpomyia sp.					
Dasyhelia sp.					
Chironomidae sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.	14	72		14	
Chironomus (Dicrotendipes) sp.				157	
Procladius sp.	172	186	29	114	
Microtendipes sp.					
Ephemeroptera					
Ephemerella sp.					
Caenis sp.			57		
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.		29			
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.				14	
Coeleoptera					
Berosus sp.					
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Ancmalagrion hastatum					
Celethemis sp.	43		14		
Lestes sp.					
Pachydiplax longipennis					
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca	72				
Oligochaeta					
Tubificidae sp. x	400	57		29	
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	729	587	157	414	

Table E26. Summary of macroinvertebrates collected in Control Pond on September 14, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	100	43	286	72	57
Chrysops sp.	14				
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.			72	29	
Chironomus (Dicrotendipes) sp.			400		343
Procladius sp.	114		286	32	57
Microtendipes sp.	200		29		
Ephemeroptera					
Ephemerella sp.					
Caenis sp.			286		29
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.		14	29		
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.	129	29			
Coeleoptera					
Berosus sp.					
Lepidoptera					
Paradonyx sp.					
Hirudinea					
Piscicolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.	14				
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bell					
Anomalagrion hastatum					
Celithemis sp.				14	
Lestes sp.					
Pachydiplax longipennis					14
Tetragoneuria sp.					
Gomphus cavillaris		14			14
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca		601		86	43
Oligochaeta					
Tubificidae sp. x	14	57	57	100	57
Tubificidae sp y					
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	585	758	1445	333	614

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Table E27. Summary of macroinvertebrates collected in Drained Engine Pond on September 14, 1972.

Taxa	Population Density (#/m^2)				
	Station 1	Station 2	Station 3	Station 4	Station 5
Diptera					
Chaoborus punctipennis	372	186	29	172	272
Chrysops sp.	14			29	
Bezzia sp.					
Palpomyia sp.					
Dasyhelia sp.					
Tanytarsus sp.					
Chironomus (Chironomus) sp.					
Chironomus (Dicrotendipes) sp.					
Procladius sp.	372	400	329	244	
Ephemeroptera					
Ephemerella sp.					
Caenis sp.			29		
Nematoda					
Rhabditina sp.					
Trichoptera					
sp. x					
Psychomyiidae sp.					
Polycentropus sp.		14	14		
Cyrnellus sp.					
Leptocella sp.					
Phylocentropus sp.					
Leptocerus americanus					
Oecetis sp.					
Coleoptera					
Berosus sp.					
Lepidoptera					
Paraponyx sp.			14		
Hirudinea					
Pisciolidae sp.					
Hellobdella stagnalis					
Illinobdella sp.					
Hellobdella sp.					
Illinobdella moorei					
Illinobdella alba					
Glossiphonia sp.					14
Odonata					
Coenagrionidae sp.					
Orthemis ferruginea					
Argia sp.					
Ischnura					
Libellulidae					
Dythemis sp.					
Erythemis sp.					
Nannothemis bella					
Anomalagrion hastatum					
Celethemis sp.					
Lestes sp.					
Pachydiplax longipennis		14			
Tetragoneuria sp.					
Gomphus cavillaris					
Enallagma sp.					
Amphiagrion saucium					
Tramea carolina					
Amphipoda					
Hyallela azteca	72	86	29	72	
Oligochaeta					
Tubificidae sp. x			29	200	14
Tubificidae sp y	29			29	
Limnodrillis sp.					
Oligochaeta sp b					
Density of organisms per station	859	700	473	1246	300

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Table E28. Summary of macroinvertebrates collected in Drainless Engine Pond on October 13, 1972.

Taxa	Population Density (#/m²) Station 1a	1b	Station 2a	2b	Station 3a	3b	Station 4a	4b	Station 5a	5b
Diptera										
Chaoborus punctipennis		631	43	127		84	4413			
Chrysops sp.			43							
Bezzia sp.			43							
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.										
Chironomus (Chironomus) sp.		672				1051				
Chironomus (Dicrotendipes) sp.			967	420		2732				
Procladius sp.				504	127			172		
Microtendipes sp.										
Clinotanypus sp.										
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus										
Clinotanypus thoracicus										
Ablabesmyia peleensis										
Ablabesmyia rhamphe										
Ablabesmyia ornata										
Ablabesmyia janta										
Ablabesmyia sp.		420				588				
Harnischia collator										
Nilotanypus sp.										
Chironomus (Tribelos) sp.										
Larsia berneri										
Larsia lurida										
Chironomus (Limnochironomus) tenuicaudatus										
Coelotanypus concinnus										
Tanypus punctipennis										
Psectrotanypus										
Diamesa sp.										
Polypedilum fallax				1051						
Polypedilum sp.										
Glyptotendipes				127						
Conchapelopia sp.										
Chironomus (Dicrotendipes) nervosus										
Chironomus (Einfeldia) brunneipennis										
Dicrotendipes modestus										
Pentaneurini sp.										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.		84								
Nematoda										
Rhabditina sp.										
Odonata										
Coenagrionidae sp.										
Celethemis sp.			43	43		127				
Lestes sp.										
Pachydiplax longipennis					43					
Tetragoneuria sp.										
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina										
Amphipoda										
Hyallela azteca		295	43	168	504	631				
Oligochaeta										
Tubificidae sp. x		6103	672	379	2017		43			
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b			127							
Density of organisms per station		8205	1981	2819	2691	5218	4456	172		

Table E29. Summary of macroinvertebrates collected in Drained Engine Pond on October 13, 1972.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	379	211	43	84	127	168	127			
Chrysops sp.	43									
Bezzia sp.			43		43			43		
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.	252	127								
Chironomus (Chironomus) sp.	127	84								
Chironomus (Dicrotendipes) sp.										
Procladius sp.	504	1849	840	379	43	127	211	127		
Microtendipes sp.										
Clinotanypus sp.										
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus	252	84								
Clinotanypus thoracicus										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.	1093	420			127	252	211	43		
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.										
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.										
Hirudinea										
Pisciolidae sp.										
Hellobdella stagnalis										
Illinobdella sp.										
Hellobdella sp.					43					
Cladocera										
Daphnia sp.										
Odonata										
Coenagrionidae sp.										
Orthemis ferruginea										
Argia sp.										
Ischnura										
Libellulidae										
Dythemis sp.										
Erythemis sp.										
Nannothemis bella										
Anomalagrion hastatum										
Celethemis sp.										
Lestes sp.							43			
Pachydiplax longipennis										
Tetragoneuria sp.										
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina	84	43								
Amphipoda										
Hyallela azteca	504	252		168	252	168	504	43		
Oligochaeta										
Tubificidae sp. x	547	295	252	463		336	211			
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	3785	3365	1178	1094	635	1051	1307	256		

Table E30. Summary of macroinvertebrates collected in Control Pond on October 13, 1972.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	295	295	588	968	756	547	43	127	504	756
Chrysops sp.	127			84						
Bezzia sp.	84		211			43			43	
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.			2941							
Chironomus (Chironomus) sp.	43									
Chironomus (Dicrotendipes) sp.	1681	1976	212		420	336	2900	2521	2101	2564
Procladius sp.	840	252	211	672			379	252		
Microtendipes sp.										
Clinotanypus sp.			602					168	547	631
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus		43								
Ablabesmyia sp.									379	631
Harnischia collator										
Nilotanypus sp.										
Chironomus (Tribelos) sp.										
Larsia berneri		43								
Larsia lurida										
Polypedilum sp.										
Glyptotendipes		127								
Conchapelopia sp.			588							
Chironomus (Dicrotendipes) nervosus					2941	2480				
Chironomus (Einfeldia) brunneipennis										
Dicrotendipes modestus										
Pentaneurini sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.			84	43						
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.				43						43
Coeleoptera										
Berosus sp.										
Odonata										
Coenagrionidae sp.										
Orthemis ferruginea										
Argia sp.										
Ischnura										
Libellulidae										
Dythemis sp.										
Erythemis sp.										
Nannothemis bella										
Anomalagrion hastatum										
Celethemis sp.			84		43	168	127			
Lestes sp.										
Pachydiplax longipennis					43			43	43	84
Tetragoneuria sp.										
Gomphus cavillaris							43	43	252	336
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina								84		
Amphipoda										
Hyallela azteca			43	252	43	84		84		
Oligochaeta										
Tubificidae sp. x		211	379				379	336	631	463
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b				168			43	43	43	127
Density of organisms per station	3034	2947	5943	2230	4246	3658	3914	3701	4543	5635

Table E31. Summary of macroinvertebrates collected in Drainless Engine Pond on December 27, 1972.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	129	129	688	129			1462	1247		
Chrysops sp.	43		43							
Bezzia sp.			43							
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.	258			473	43		43			
Chironomus (Chironomus) sp.	215	43	129	86		129				
Chironomus (Dicrotendipes) sp.		86	989	86		946				
Procladius sp.		1118	258	860	129		2193	1849		
Ephemeroptera										
Ephemerella sp.										
Caenis sp.	86	344	172	86		473				
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.										
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.			86			129	43			
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.			129			43				
Hirudinea										
Pisciolidae sp.										
Hellobdella stagnalis										
Illinobdella sp.										
Odonata										
Coenagrionidae sp.										
Orthemis ferruginea										
Argia sp.										
Ischnura										
Libellulidae										
Dythemis sp.										
Erythemis sp.										
Nannothemis bella										
Anomalagrion hastatum										
Celethemis sp.										
Lestes sp.										
Pachydiplax longipennis										
Tetragoneuria sp.						86				
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina		43	43							
Amphipoda										
Hyallela azteca						129				
Oligochaeta										
Tubificidae sp. x	86	301	559					86		
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	817	2064	3139	1720	172	1935	3741	3182		

Table E32. Summary of macroinvertebrates collected in Drained Engine Pond on December 27, 1972.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	43	43	43	43	86	43				516
Chrysops sp.					215			86		
Bezzia sp.										
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.						129				
Chironomus (Chironomus) sp.	43		43		43					
Chironomus (Dicrotendipes) sp.	258									
Procladius sp.	903		989	86	344	688	118	473	43	172
Microtendipes sp.						43				
Clinotanypus sp.	43									
Chironomus (Cryptochironomus) sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.				43	129	129				
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus	43		86							
Oecetis sp.							43			
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.										
Hirudinea										
Pisciolidae sp.										
Helicbdella stagnalis										
Illinobdella sp.										
Helobdella sp.										
Illinobdella moorei										
Illinobdella alba										
Glossiphonia sp.										
Odonata										
Coenagrionidae sp.										
Orthemis ferruginea										
Argia sp.										
Ischnura										
Libellulidae										
Dythemis sp.										
Erythemis sp.										
Nannothemis bella										
Anomalagrion hastatum										
Celethemis sp.										
Lestes sp.			43							
Pachydiplax longipennis										
Tetragoneuria sp.										
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina					43					
Amphipoda										
Hyallela azteca	86		43							
Oligochaeta										
Tubificidae sp. x	301		129	43				86		
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	1720	43	1376	215	860	1032	161	645	43	688

Table E33. Summary of macroinvertebrates collected in Control Pond on December 27, 1972.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis				86		86	43	344	1505	43
Chrysops sp.									43	
Bezzia sp.			215						43	
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.									86	
Chironomus (Chironomus) sp.			86			43			258	
Chironomus (Dicrotendipes) sp.										
Procladius sp.	1376	301	473	129	258	2623				817
Microtendipes sp.										
Clinotanypus sp.	215	86		86	258	559	43			
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.	43		86		129	258	43	215	43	
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.										
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.			43							129
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.			43		43		43	86		
Hirudinea										
Pisciolidae sp.										
Odonata										
Coenagrionidae sp.										
Orthemis ferruginea										
Argia sp.										
Ischnura										
Libellulidae										
Dythemis sp.										
Erythemis sp.										
Hannothemis bella										
Anomalagrion hastatum										
Celethemis sp.										
Lestes sp.						43				
Pachydiplax longipennis										
Tetragoneuria sp.				86		43				
Gomphus cavillaris										
Enallagma sp.		43						43		
Amphiagrion saucium										
Tramea carolina										
Amphipoda		43								
Hyallela azteca										
Oligochaeta										
Tubificidae sp. x										
Tubificidae sp y				43	258	86	129			86
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	1634	473	946	430	946	3741	301	688	1978	1075

Table E34. Summary of macroinvertebrates collected in Drainless Engine Pond on January 31, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	215	645	473	258						
Chrysops sp.										
Bezzia sp.								43		
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.			172	129						
Chironomus (Chironomus) sp.				43	4429	645	344			
Chironomus (Dicrotendipes) sp.							559			
Procladius sp.	86	1505	387	301	129	172	172			
Microtendipes sp.										
Clinotanypus sp.										
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus				43						
Coelotanypus concinnus					43					
Tanypus punctipennis				43						
Apsectrotanypus							43			
Diamesa sp.					86					
Polypedilum fallax										
Polypedilum sp.										
Glyptotendipes										
Conchapelopia sp.										
Chironomus (Dicrotendipes) nervosus										
Chironomus (Einfeldia) brunneipennis										
Dicrotendipes modestus										
Pentaneurini sp.										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.					86	43	129			
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.										
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.				43	43	215	43			
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.								86		
Odonata										
Coenagrionidae sp.										
Orthemis ferruginea										
Argia sp.										
Ischnura										
Libellulidae										
Dythemis sp.										
Erythemis sp.										
Nannothemis bella										
Anomalagrion hastatum										
Celethemis sp.						43	43			
Lestes sp.				86	86	43				
Pachydiplax longipennis				43	215	43	86	86		
Tetragoneuria sp.										
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina					43					
Amphipoda										
Hyallela azteca							172	43		
Density of organisms per station	301	2150	1032	989	5160	1204	1591	258		

E35. Summary of Macroinvertebrates Collected in Drained Engine Pond on January 31, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	43	215					43		645	1075
Chrysops sp.			43	215		43				
Bezzia sp.										
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.		86					43			
Chironomus (Chironomus) sp.										
Chironomus (Dicrotendipes) sp.										
Procladius sp.	989	473	301	602	344		129	215	86	1505
Microtendipes sp.										
Clinotanypus sp.										
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus	86		43							
Clinotanypus thoracicus										
Ablabesmyia peleensis										
Ablabesmyia rhamphe										
Ablabesmyia ornata	43									129
Ablabesmyia janta										
Ablabesmyia sp.										
Harnischia collator										
Nilotanypus sp.			344							
Chironomus (Tribelos) sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.	86		43	43	86		215			43
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.				86			43	43		43
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.										
Hirudinea										
Pisciolidae sp.										
Hellobdella stagnalis										
Illinobdella sp.										
Hellobdella sp.							86			
Illinobdella moorei										
Illinobdella alba										
Glossiphonia sp.										
Odonata										
Coenagrionidae sp.										
Orthemis ferruginea										
Argia sp.										
Ischnura										
Libellulidae										
Dythemis sp.										
Erythemis sp.										
Nannothemis bella										
Anomalagrion hastatum										
Celethemis sp.						43		86		
Lestes sp.							43			
Pachydiplax longipennis								43		
Tetragoneuria sp.										
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina										
Amphipoda										
Hyallela azteca				86		172	43			43
Oligochaeta										
Tubificidae sp. x							43	86		
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	1247	774	774	1032	430	258	688	473	731	2838

Table E36. Summary of macroinvertebrates collected in Control Pond on January 31, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	301			301					86	43
Chrysops sp.	43									
Bezzia sp.		43								
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.										
Chironomus (Chironomus) sp.		860		86			903			43
Chironomus (Dicrotendipes) sp.	172	989	86	43			387		430	258
Procladius sp.	473	473	473	215		430	860		301	301
Microtendipes sp.										
Clinotanypus sp.			215		129		43			215
Chironomus (Cryptochironomus) sp.				172						
Chironomus (Cryptochironomus) abortivus			172		43	43	43			
Clinotanypus thoracicus										
Ablabesmyia peleensis										
Ablabesmyia rhamphe										
Ablabesmyia ornata	129	86	172	86		43				129
Ablabesmyia janta										
Ablabesmyia sp.										
Harnischia collator										
Nilotanypus sp.		989	387	129						
Chironomus (Tribelos) sp.										
Larsia berneri										
Larsia lurida										
Chironomus (Limnochironomus) tenuicaudatus										
Coelotanypus concinnus				258		172			129	
Tanypus punctipennis										
Apsectrotanypus										
Diamesa sp.										
Polypedilum fallax										
Polypedilum sp.										
Glyptotendipes		129								
Conchapelopia sp.		1075				129			43	43
Chironomus (Dicrotendipes) nervosus										
Chironomus (Einfeldia) brunneipennis										
Dicrotendipes modestus										
Pentaneurini sp.										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.	86	43	129	86				129		344
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.					43					
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.	86		43	43	172	43	344	43	86	43
Coeleoptera										
Berosus sp.		43			43					
Lepidoptera										
Paradonyx sp.		86	43	344	129	172				
Celethemis sp.										
Lestes sp.										
Pachydiplax longipennis			43			43				
Tetragoneuria sp.	43	344	215		86	172				
Gomphus cavillaris										
Enallagma sp.						43	86			
Amphiagrion saucium										
Tramea carolina	43							43		86
Amphipoda										
Hyallela azteca		215	86		43	86	86	86		
Oligochaeta										
Tubificidae sp. x	172				172					
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	1548	5375	2064	1763	860	1376	2752	301	1075	1505

Table E37. Summary of macroinvertebrates collected in Drainless Engine Pond on February 21, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis		129				43				
Chrysops sp.										
Bezzia sp.										
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.										
Chironomus (Chironomus) sp.	43		559			860	129	516		
Chironomus (Dicrotendipes) sp.	129		1247							
Procladius sp.	903			903	516	43	129	301		
Microtendipes sp.	43			43						
Clinotanypus sp.	43		43					43		
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus	258		215	129						
Clinotanypus thoracicus										
Ablabesmyia peleensis										
Ablabesmyia rhamphe										
Ablabesmyia ornata	86		86							
Ablabesmyia janta										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.				86				86		
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.		86		43						
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.				43		86	43			
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.										
Hirudinea										
Pisciolidae sp.										
Hellobdella stagnalis				43		43				
Illinobdella sp.										
Hellobdella sp.										
Illinobdella moorei										
Illinobdella alba										
Glossiphonia sp.										
Turbellaria										
Tricladida sp.										
Phagocata sp.				215	103	43		43		
Odonata										
Coenagrionidae sp.										
Ancmalagrion nastatum										
Celethemis sp.							129			
Lestes sp.						43				
Pachydiplax longipennis		43				86	301	43		
Tetragoneuria sp.										
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina										
Amphipoda										
Hyallela azteca		215		430	43	1247		43		
Density of organisms per station	1505	473	2150	1935	662	2494	731	1075		

Table E38. Summary of macroinvertebrates collected in Drained Engine Pond on February 21, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	301	1632		129				43	129	
Chrysops sp.				86	86	43				
Bezzia sp.				86	86	43				
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.				129	86		387	129		
Chironomus (Chironomus) sp.								43		
Chironomus (Dicrotendipes) sp.										
Procladius sp.	430		731	774	516	344	1075	1204	43	559
Microtendipes sp.										
Clinotanypus sp.	129		215	215				215		43
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus				215						43
Clinotanypus thoracicus										
Ablabesmyia peleensis										
Ablabesmyia rhamphe										
Ablabesmyia ornata			129	172				86		43
Ablabesmyia janta										
Ablabesmyia sp.										
Harnischia collator										
Nilotanypus sp.										
Chironomus (Tribelos) sp.										
Larsia berneri										
Larsia lurida										
Chironomus (Limnochironomus) tenuicaudatus										
Coelotanypus concinnus										
Tanypus punctipennis				86						
Apsectrotanypus										
Diamesa sp.										
Polypedilum fallax										
Polypedilum sp.										
Glyptotendipes										
Conchapelopia sp.										
Chironomus (Dicrotendipes) nervosus										
Chironomus (Einfeldia) brunneipennis										
Dicrotendipes modestus										
Pentaneurini sp.										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.				86				129		
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.				86				172	129	382
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.				129		86	43	43		43
Odonata										
Coenagrionidae sp.										
Lestes sp.										
Pachydiplax longipennis				43		43				
Tetragoneuria sp.				129				86		
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina										
Amphipoda										
Hyallela azteca										
Oligochaeta				172	129		473			
Tubificidae sp. x										
Tubificidae sp y	43			172			817		387	
Limnodrillis sp.						86				
Oligochaeta sp b										
Density of organisms per station	903	1632	1075	2709	903	645	2795	2150	688	1113

Table E39. Summary of macroinvertebrates collected in Control Pond on February 21, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	1032	129			43		86			86
Chrysops sp.		43								
Bezzia sp.			86							
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.										
Chironomus (Chironomus) sp.			258	215			43	559		
Chironomus (Dicrotendipes) sp.			516						258	
Procladius sp.		1161	344	946	387	1075	1935	2107	430	
Microtendipes sp.										
Clinotanypus sp.		301		43	172	559	43			
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus		516	2967		387	301	301			
Clinotanypus thoracicus										
Ablabesmyia peleensis										
Ablabesmyia rhamphe										
Ablabesmyia ornata				43		172	43			
Ablabesmyia janta										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.	86	43	43	86	86	86	258	172		
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.										
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.	129		129		86		172	43		43
Coeleoptera										
Berosus sp.										
Lepidoptera										
Paradonyx sp.		43		86	215	86				43
Odonata										
Celethemis sp.										
Lestes sp.										
Pachydiplax longipennis				43			43			
Tetragoneuria sp.				86	215	86				
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina	43	43								
Amphipoda										
Hyallela azteca	43									
Oligochaeta								215		
Tubificidae sp. x		86	602							
Tubificidae sp y							430	215		774
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	1333	2365	4945	1548	1591	2365	3354	3311	688	946

Table E40. Summary of marcoinvertebrates collected in Drained Engine Pond on March 21, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	516		86						129	
Chrysops sp.						43				
Bezzia sp.	43									
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.										129
Chironomus (Chironomus) sp.	43				172	43		86	43	
Chironomus (Dicrotendipes) sp.		43	215							
Procladius sp.	1892	774	258	688	43	602	946	1161	903	731
Microtendipes sp.										43
Clinotanypus sp.										
Chironomus (Cryptochironomus) sp.							43			
Chironomus (Cryptochironomus) abortivus	43									
Clinotanypus thoracicus	43		43	86	43	86	172	129		43
Ablabesmyia peleensis				86						
Ablabesmyia rhamphe	344		301							86
Ablabesmyia ornata		258		43						
Ablabesmyia janta			387	129	129					
Ablabesmyia sp.										
Harnischia collator								86		
Nilotanypus sp.		43								
Chironomus (Tribelos) sp.		43								
Larsia berneri		43				86				
Larsia lurida		43								
Ephemeroptera										
Ephemerella sp.										
Caenis sp.										
Nematoda	43		215					258	43	
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.										
Cyrnellus sp.				129				43	43	
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.										
Coeleoptera			43	43			43			
Berosus sp.										
Lepidoptera										
Paradonyx sp.										
Odonata								86		
Celethemis sp.										
Lestes sp.	301		172		43	43	43			43
Pachydiplax longipennis			86			43		43		
Tetragoneuria sp.			43		43	43		86		
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina										
Amphipoda										
Hyallela azteca										
Oligochaeta	43		86	43	688	516			86	43
Tubificidae sp. x										
Tubificidae sp y		43	86			86		129		43
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	3311	1290	2021	1247	1161	1591	1247	2107	1247	1161

Table E41. Summary of macroinvertebrates collected in Control Pond on March 21, 1973.

Taxa	Population Density (#/m^2)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis			172	774		43				43
Chrysops sp.										
Bezzia sp.										
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.										
Chironomus (Chironomus) sp.			258					172		
Chironomus (Dicrotendipes) sp.										
Procladius sp.	744	443	817	946		129		1634	817	1290
Microtendipes sp.										
Clinotanypus sp.										
Chironomus (Cryptochironomus) sp.								143		
Chironomus (Cryptochironomus) abortivus				172						
Clinotanypus thoracicus	129					43		301		43
Ablabesmyia peleensis										
Ablabesmyia rhamphe		.43						43		
Ablabesmyia ornata				86					43	43
Ablabesmyia janta			258					43		
Ablabesmyia sp.										
Harnischia collator										
Nilotanypus sp.										
Chironomus (Tribelos) sp.										
Larsia berneri										
Larsia lurida										
Chironomus (Limnochironomus) tenuicaudatus				43						
Coelotanypus concinnus										
Ephemeroptera										
Ephemerella sp.										
Caenis sp.	43	86	387	258		43	172		86	129
Nematoda										
Rhabditina sp.										
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.										
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.										
Coeleoptera										43
Berosus sp.										
Lepidoptera										
Paradonyx sp.						86				
Odonata										
Celethemis sp.										
Lestes sp.	43	43			43					
Pachydiplax longipennis	43									
Tetragoneuria sp.				43	43					
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina										
Amphipoda										
Hyallela azteca										
Oligochaeta				43	86	86				
Tubificidae sp. x										
Tubificidae sp y	86		215	129	129	43				
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	1088	615	2107	2494	301	473	172	2336	946	1591

Table E42. Summary of macroinvertebrates collected in Drainless Engine Pond on March 21, 1973.

Taxa	Population Density (#/m²)									
	Station		Station		Station		Station		Station	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
Diptera										
Chaoborus punctipennis	645	172								
Chrysops sp.										
Bezzia sp.										
Palpomyia sp.										
Dasyhelia sp.										
Chironomidae sp.										
Tanytarsus sp.										
Chironomus (Chironomus) sp.			129	559	1806	645		43		
Chironomus (Dicrotendipes) sp.										
Procladius sp.	989	344	1376	731	817	129	129	43		
Microtendipes sp.		143								
Clinotanypus sp.										
Chironomus (Cryptochironomus) sp.										
Chironomus (Cryptochironomus) abortivus								43		
Clinotanypus thoracicus				43						
Ablabesmyia peleensis		86			43					
Ablabesmyia rhamphe						43				
Ablabesmyia ornata	86	86								
Ablabesmyia janta		86		129						
Ablabesmyia sp.										
Harnischia collator										
Nilotanypus sp.		43		86						
Chironomus (Tribelos) sp.										
Larsia berneri										
Larsia lurida										
Chironomus (Limnochironomus) tenuicaudatus										
Coelotanypus concinnus										
Tanypus punctipennis										
Apsectrotanypus										
Diamesa sp.	645	172								
Trichoptera										
sp. x										
Psychomyiidae sp.										
Polycentropus sp.						43				
Cyrnellus sp.										
Leptocella sp.										
Phylocentropus sp.										
Leptocerus americanus										
Oecetis sp.				86		43				
Odonata										
Anomalagrion hastatum										
Celethemis sp.										
Lestes sp.						43				
Pachydiplax longipennis				86						
Tetragoneuria sp.						43				
Gomphus cavillaris										
Enallagma sp.										
Amphiagrion saucium										
Tramea carolina	43	43								
Amphipoda										
Hyallela azteca						129		129		
Oligochaeta										
Tubificidae sp. x	43			43						
Tubificidae sp y										
Limnodrillis sp.										
Oligochaeta sp b										
Density of organisms per station	2451	1175	1505	1736	2666	1118	129			

APPENDIX F

TWO-WAY ANOVA TESTING

Table F1. Mean total inorganic carbon for each season and treatment

N[a]	Season[d]	TRT[b]	Mean[c]
3	1	1	0.66
3	1	2	0.40
3	1	3	0.36
3	2	1	0.60
3	2	2	0.63
3	2	3	0.46
4	3	1	0.62
4	3	2	0.97
4	3	3	0.50
4	4	1	0.75
4	4	2	0.72
4	4	3	0.40

[a] N = number of observations
[b] Treatment 1 = Drainless
2 = Drained
3 = Control
[c] TIC man (mg/1)
[d] Season 1 = Winter (Dec., Jan., Feb.)
2 = Spring (Mar., Apr., May)
3 = Summer (June, July, Aug.)
4 = Fall (Sep., Oct., Nov.)

Table F2. Two-way analysis of variance for monthly TIC data.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	Std. Dev.
Regression	32	2.57976190	0.08061756	1.05153	0.4972	0.78897546	
Error	9	0.69000000	0.07666667				0.27688746
Corrected Total	41	3.26976190					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Month	10	1.02976190	1.34317	0.3334	1.02976190	1.34317	0.3334
TRT	2	0.59619048	3.88820	0.0600	0.41263158	2.69108	0.1205
Month*TRT	20	0.95380952	0.62205	0.8201	0.95380952	0.62205	0.8201

Table F3. Two-way analysis of variance for seasonal TIC data.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	St. Dev.
Regression	11	1.27059524	0.11550866	1.73335	0.1135	0.38858953	
Error	30	1.99916667	0.06663889				0.25814509
Corrected Total	41	3.26976190					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Season	3	0.27170635	1.35910	0.2735	0.27170635	1.35910	0.2735
TRT	2	0.59619048	4.47329	0.0195	0.52384921	3.93051	0.0297
Season*TRT	6	0.40269841	1.00717	0.4399	0.40269841	1.00717	0.4399

Table F4. Mean grassbed productivity for each month and treatment.

N[a]	Month[b]	TRT[c]	Productivity[d]
0	1	1	0.07
2	1	2	1.59
2	1	3	0.06
4	2	1	2.18
4	2	2	1.86
4	2	3	1.81
6	4	1	1.24
6	4	2	2.08
6	4	3	1.23
2	6	1	2.36
2	6	2	4.99
2	6	3	3.00
4	7	1	2.58
4	7	2	4.22
4	7	3	2.19
2	9	1	2.23
2	9	2	3.10
2	9	3	1.03
2	11	1	1.16
2	11	2	2.28
2	11	3	1.31

[a] N = number of data points
[b] Month
[c] Treatments (i.e. Pond) 1 Drainless Pond
2 Drained Engine Pond
3 Control Pond
[d] g Cm^{-2} day^{-1}

Table F5. Mean grassbed productivity for each season and treatment.

N[a]	Season[b]	TRT[c]	Productivity[d]
6	1	1	1.48
6	1	2	1.77
6	1	3	1.23
6	2	1	1.24
6	2	2	2.08
6	2	3	1.23
6	3	1	2.51
6	3	2	4.48
6	3	3	2.46
4	4	1	1.69
4	4	2	2.19
4	4	3	1.17

[a] N = Number of data points
[b] Seasons of the year: 1= Winter
2= Spring
3= Summer
4= Fall
[c] Treatments (i.e. Ponds) 1 Drainless Engine Pond
2 Drained Engine Pond
3 Control Pond

[d]= Cm^{-2} day^{-1}

Table F6. Two-way analysis of variance for monthly grassbed productivity data.

Source	DF	Sum of Squares	Mean Square	F-Value	Prob > F	R-Square	St. Dev.
Regression	20	71.89070682	3.59453534	14.23131	0.0001	0.86348169	
Error	45	11.36607500	0.25257944				0.50257283
Corrected Total	65	83.25678182					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F-Value	Prob > F
Month	6	44.44329571	29.32628	0.0001	44.44329571	29.32628	0.0001
TRT	2	15.78284545	31.24333	0.0001	15.84692830	31.37019	0.0001
Month*TRT	12	11.66456566	3.84848	0.0007	11.66456566	3.84848	0.0007

Table F7. Two-way analysis of variance for seasonal grassbed productivity data.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	St. Dev.
Regression	11	55.49330682	5.04484607	9.81223	0.0001	0.66653197	
Error	54	27.76347500	0.51413843				0.71703447
Corrected Total	65	83.25678182					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Season	3	33.77104015	21.89491	0.0001	33.77104015	21.89491	0.0001
TRT	2	15.78284545	15.34883	0.0001	14.77978519	14.37335	0.0001
Season TRT	6	5.93942121	1.92536	0.0927	5.93942121	1.92536	0.0927

Table F8. Two-way analysis of variance for seasonal grassbed productivity data.

Treatment Comparisons	df	Mean Square	F-Value
Between Engines within January	2	1.5504	6.14**
Between Engines within February	2	0.1607	0.64
Between Engines within April	2	1.4310	5.67**
Between Engines within June	2	3.7667	14.91**
Between Engines within July	2	4.6415	18.38**
Between Engines within September	2	2.1606	8.55**
Between Engines within November	2	0.0126	0.05
Between Months within Drainless Engine	6	2.1041	8.33**
Between Months within Drained Engine	6	5.2026	20.91**
Between Months within Control	6	1.9646	7.78**

Table F9. Mean plankton counts for each season and treatment.

N[a]	Season[b]	TRT[c]	Means (Cells/ml)
13	1	1	4200
13	1	2	4462
13	1	3	2668
9	2	1	7640
9	2	2	3966
9	2	3	783
11	3	1	1013
11	3	2	2694
11	3	3	2282
6	4	1	1794
6	4	2	1559
6	4	3	1871

[a] N = Number of data points

[b] Seasons of year:
1 = Winter (Dec., Jan., Feb.)
2 = Spring (Mar., Apr., May)
3 = Summer (Jun., Jul., Aug.)
4 = Fall (Sep., Oct., Nov.)

[c] Treatments (i.e. Ponds):
1 = Drainless Engine Pond
2 = Drained Engine Pond
3 = Control Pond

Table F10. Mean plankton counts for each month and treatment

N[a]	Month[b]	TRT[c]	Means (Cells/ml)
4	1	1	3474
4	1	2	6252
4	1	3	4379
4	2	1	7792
4	2	2	6154
4	2	3	2475
6	3	1	10483
6	3	2	4617
6	3	3	170
3	4	1	1954
3	4	2	2664
3	4	3	2010
2	6	1	942
2	6	2	662
2	6	3	719
3	7	1	1306
3	7	2	6212
3	7	3	5206
6	8	1	891
6	8	2	1610
6	8	3	1341
2	9	1	2069
2	9	2	2157
2	9	3	3667
1	10	1	5238
1	10	2	4014
1	10	3	3032
3	11	1	463
3	11	2	342
3	11	3	288
5	12	1	1909
5	12	2	1676
5	12	3	1453

[a] N = Number of data points

[b] Month

[c] Treatments (i.e. pond)
1 = Drainless Engine Pond
2 = Drained Engine Pond
3 = Control Pond

Table F11. Two-way analysis of variance for monthly plankton count data.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	STD DEV
Regression	32	827714975.38889	25866092.98090	0.96800	0.5261	0.26941269	
Error	84	2244578976.83333	26721178.29563				5169.25316614
Corrected Total	116	3072293952.22222					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Month	10	382142289.76667	1.43011	0.1810	382142289.76667	1.43011	0.1810
TRT	2	65457468.94017	1.22482	0.2987	22629254.03545	0.43243	0.6619
Month*TRT	20	380115216.68205	0.71126	0.8043	380115216.68205	0.71126	0.8043

Table F12. Two-way analysis of variance for seasonal plankton count data.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	STD DEV
Regression	11	373069355.57071	33915395.96097	1.31931	0.2236	0.12143023	
Error	105	2699224596.65152	25706900.92049				5070.19732560
Corrected Total	116	3072293952.22222					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Season	3	119568916.43447	1.55041	0.2045	119568916.43447	1.55041	0.2045
TRT	2	65457468.94017	1.27315	0.2836	59268764.25626	1.15278	0.3199
Season*TRT	6	188042970.19606	1.21915	0.3017	188042970.19606	1.21915	0.3017

Table F13. Mean phytoplankton productivity for each month and treatment.

N[a]	Month[b]	TRT[c]	Productivity[d]
4	1	1	0.054
4	1	2	0.036
5	1	3	0.063
4	2	1	0.573
4	2	2	0.440
3	2	3	0.485
4	3	1	0.583
3	3	2	1.725
3	3	3	0.010
2	4	1	0.165
3	4	2	0.126
3	4	3	0.275
1	6	1	0.128
1	6	2	0.074
1	6	3	0.174
2	7	1	0.399
3	7	2	0.237
3	7	3	0.264
1	9	1	0.242
1	9	2	0.250
1	9	3	0.518
3	10	1	0.303
3	10	2	0.382
3	10	3	1.009
6	11	1	0.136
6	11	2	0.115
4	11	3	0.461
2	12	1	0.230
3	12	2	0.245
3	12	3	0.599

[a] N = Number of data points

[b] Month #1 = Jan.

[c] Treatments (i.e. Pond) 1 = Drainless Engine Pond
2 = Drained Engine Pond
3 = Control Pond

[d] $gCm^{-3}day^{-1}$

Table F14. Two-way analysis of variance for monthly phytoplankton productivity.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	STD DEV
Regression	29	10.38931782	0.35825234	6.23003	0.0001	0.75698750	
Error	58	3.33523880	0.05750412				0.23980016
Corrected Total	87	13.72455662					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Month	9	4.15677479	8.03184	0.0001	4.12737529	7.97503	0.0001
TRT	2	0.18395180	1.49947	0.2092	0.13034798	1.13338	0.3294
Month*TRT	18	6.04859124	5.84363	0.0001	6.04859124	5.84363	0.0001

Table F15. Two-way analysis of variance for monthly phytoplankton productivity.

Treatment Comparison	DF	Mean Square	F
Between Ponds within January	2	.0009	.02
Between Ponds within February	2	.0182	.32
Between Ponds within March	2	2.3046	40.08**
Between Ponds within April	2	.0175	.30
Between Ponds within June	2	.0025	.04
Between Ponds within July	2	.0171	.30
Between Ponds within September	2	.0247	.43
Between Ponds within October	2	.04491	7.81**
Between Ponds within November	2	.2328	4.05*
Between Ponds within December	2	.1124	1.95*
Between Months within Drainless Engine Ponds	9	.1244	2.16*
Between Months within Drained Engine Pond	9	.7476	13.00**
Between Months within Control	9	.2709	4.71**

* : P<.05
** : P<.01

Table F16. Mean benthic macroinvertebrate diversity indices for each month and treatment.

N[a]	Month[b]	TRT[c]	Diversity[d]
1	1	1	1.34
1	1	2	1.07
1	1	3	1.29
2	2	1	1.17
2	2	2	1.06
2	2	3	1.25
2	3	1	1.50
2	3	2	0.85
2	3	3	1.37
1	4	1	1.25
1	4	2	1.02
1	4	3	1.56
1	5	1	1.53
1	5	2	1.37
1	5	3	1.95
1	6	1	1.49
1	6	2	1.40
1	6	3	1.88
2	8	1	1.31
2	8	2	1.33
2	8	3	1.52
1	9	1	1.33
1	9	2	1.35
1	9	3	1.69
2	10	1	1.25
2	10	2	1.26
2	10	3	1.30
1	12	1	1.15
1	12	2	1.24
1	12	3	1.28

[a] N = Number of data points

[b] Month #1 = Jan.

[c] Treatments (i.e. Ponds) 1 = Drainless Engine Pond
2 = Drained Engine Pond
3 = Control Pond

[d] Shannon-Weaver index

Table F17. Mean benthic macroinvertebrate diversity indices for seasons and treatment.

N[a]	Season[b]	TRT[c]	Diversity[d]
4	1	1	1.20
4	1	2	1.11
4	1	3	1.26
4	2	1	1.44
4	2	2	1.02
4	2	3	1.56
3	3	1	1.37
3	3	2	1.35
3	3	3	1.64
3	4	1	1.27
3	4	2	1.35
3	4	3	1.43

[a] N = Number of data points

[b] Seasons of year:
1 = Winter (Dec., Jan., Feb.)
2 = Spring (Mar., Apr., May)
3 = Summer (Jun., Jul., Aug.)
4 = Fall (Sep., Oct. Nov.)

[c] Treatments (i.e. Pond):
1 = Drainless Engine Pond
2 = Drained Engine Pond
3 = Control Pond

[d] Shannon-Weaver index

Table F18. Two-way analysis of variance for monthly macroinvertebrate diversity indices.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	STD DEV
Regression	29	1.96319762	0.06769647	0.41522	0.9740	0.50086074	
Error	12	1.95645000	0.16303750				0.40277902
Corrected Total	41	3.91964762					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Month	9	0.80896429	0.55131	0.8117	0.80896429	0.55131	0.8117
TRT	2	0.53224762	1.63229	0.2353	0.57922500	1.77636	0.2101
Month*TRT	18	0.62198571	0.21194	0.9980	0.62198571	0.21194	0.9980

Table F19. Two-way analysis of variance for seasonal macroinvertebrate diversity indices.

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R-Square	STD DEV
Regression	11	1.25173095	0.11379372	1.27958	0.2824	0.31934783	
Error	30	2.66791667	0.08893056				0.29821227
Corrected Total	41	3.91964762					

Source	DF	Sequential SS	F Value	Prob > F	Partial SS	F Value	Prob > F
Season	3	0.37102540	1.39069	0.2640	0.37103540	1.39069	0.2640
TRT	2	0.53224762	2.99249	0.0638	0.47929563	2.69477	0.0823
Season*TRT	6	0.34845794	0.65305	0.6893	0.34845794	0.65305	0.6893

APPENDIX G

PHYTOPLANKTON AND PROTOZOANS COLLECTED

Table G1. Abundance[a] of blue-green algae (Cyanophyceae) in the three test ponds.

Pond/Taxa	Abundance[a]																																									
Drainless Engine Pond	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
BLUE GREEN ALGAE (Cyanophyceae)																																										
Anabaena sp.	R		R	R				R								R			NO SAMPLE					R	NO SAMPLE		R							U			R		U		R	
Anabaenopsis sp.	R						R																																			
Anacystis marina	D	D					D	D	D	A	A	A	D	A							A	A										D	D	D		D	D	D	A	D	D	A
Aphanizomenon sp.															R																											
Chroococcus sp.																																							U			
Gloethece linearis						D																											R	C			U	R	R			U
Gomphospheria sp.																																								R		
Lyngbya sp.				R																																						
Merismopedia punctata														R				R						R														U	U		U	
Merismopedia glauca			R																																							
Microcoleus																																									R	
Polycystis (Microcystis) aeruginosa																																				D						
Osillataria sp.												R																														
Schizothrix calcicola		R																																								
Drained Engine Pond	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
BLUE GREEN ALGAE (Cyanophyceae)																																										
Anabaena sp.					R											R			NO SAMPLE					R	NO SAMPLE		R	R						R			R	U	R		R	R
Anabaenopsis sp.	R																																									
Anacystis marina	D	D						D	D	A		D	D	D		R				A	D			A					D			D	D	D	D	D	D			D	D	D
Apanizomenon sp.				R		R																																				
Chroococcus sp.																																			R							
Gloethece linearis			D		D	A																												D	U	C	U			U		A
Haplosiphon sp.																																										
Lyngbya sp.			R		R																														R							
Marssoniella sp.																	R																								R	
Merismopedia punctata												R												R									R		R							R
Merismopedia glauca							R																																			
Polycystis (Microcystis)aeruginosa				R	R				R																													R				
Oscillataria sp.									R			R																														
Control Pond	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
BLUE GREEN ALGAE (Cyanophyceae)																																										
Anabaena sp.						R		R			R		R	R		R			NO SAMPLE						NO SAMPLE										R					R		
Anabaenopsis sp.	R			U			R		R																																	
Anacystis marina	D	D					D	D	D		D	D	D	A		R					A			D									D	D	D	D	A		A	A		A
Aphanizomenon sp.			R			R																																				
Aphanocapsa sp.								R																																		
Chroococcus sp.													R	R																												
Gloethece linearis																																							C	A		
Haplosiphon sp.													R	U																												
Lyngbya sp.		R													R																											
Marssoniella sp.							C		U																																	
Merismopedia punctata													U	R			R	R																R			R	R		R		R
Merismopedia glauca																											R															
Microcoleus sp.								C																										R			R	R	R			
Polycystis (Microcystis) aeruginosa			R					R																											D							
Oscillataria sp.																				R														R								
Raphidiopsis curvata			A		A	D																																				
Schizothrix calcicola													R	R																												
Trichodesmium lacustre									R																																	

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[a] R=rare,1-5 cells/ml.
U=uncommon,6-19 cells/ml.
C=common,20-50 cells/ml.
A=abundant,51-499 cells/ml.
D=dominant,more than 500 cells/ml.

Table G2. Abundance of green algae (Chlorophyceae) in the Drained Engine Pond.

Taxa	Abundance[a]																																									
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-10-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
Green Algae (Chlorophyceae)																																										
Ankistrodesmus falcatus										R																													R	R		
A. falcatus var. *turmidus*		U																																						R		
Arthrodesmus incus	C				R					R																										R					R	
A. octocorni																																						R				
Asterococcus limneticus	A		R	A	R																													C	R			R	U			
Chlamydomonas sp.	C																																									
Closteriopsis longissima																	R																									
Closterium sp.																																										
Coelastrum cambricum																																									R	
Cosmarium sp.			R	R	R	R		R													R			R											R						U	
Crucigenia americana													R																													
Cylindrocystis sp.					R					R				R										R																		U
Desmidium baileyii						R																													R	R	R	R				
Docidium sp.				R															NO SAMPLE						NO SAMPLE																	
Elkatothrix gelatinosa																					R	R	A																			
Euastrum inerme			R																			R					R					R		C	U	R		R	R		R	
Gloecystis sp.																							U																			
Gymnozyga sp.				R												R								R																		
Kirchneriella sp.							C																																			
Mougeotia sp.	U		R	R	R	R		R								R		R			R	R		R									U	R				U	R	R		R
Netrium sp.																								R																R		
Oedogonium sp.			R																															R	U	R			R	U		
Oocystis sp.	C	C	U		C	U	D	A							R	R					A	U	C	U			U	R	R	U				U	U	C	C	C	A		C	C
Penium sp.							R																																			
Planktosphaeria gelatinosa	R	U	D	A	A	U																																				R
Pleurotaenia sp.			R																		R																					
Quadrigula dosteriodes																																									U	
Scenedesmus sp.	C		R																		U	U		R										U	R			R			U	
Schizochlamys sp.																		R																								
Sirogonium sp.	U																																									
Sphaerocystis sp.							A											R				C	A	A			A	C		U					C			R	R		U	A
Spondylosium sp.																R																			R				R			
Staurastrum sp.		R	U	U	R										R	R	R				R	R	R	R										R	R				R	R	U	R
Tetrallantas lagerheimii			U																																							
Tetmenorus laevis																																										
Tetraedron hastatum																																										
Triploceras sp.				R																																						
Westella botryoides																																										
Xanthidium sp.					R																																					
Unidentified		A					R								A	A	C	A			A	A	A	A			A	C	C	A	A	A		A	A	C		C	A			

[a] R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml.
C = common, 20-50 cells/ml.
A = abundant, 51-499 cells/ml.
D = dominant, more than 500 cells/ml.

Table G3. Abundance of green algae (Chlorophyceae) in the Drained Engine Pond.

Taxa	Abundance[a]																																									
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
Green Algae (Chlorophyceae)																																										
Ankistrodesmus falcatus		A																	NO SAMPLE						NO SAMPLE				R							C		A				
A. falcatus var. *turmidus*		A																																								
Arthrodesmus incus			R		R																																					
A. octocorni			R																																							
Asterococcus limneticus			D	A	A																											C	R	R	R	R	R	U				A
Chlamydomonas sp.	C																																									
Chlorogonium euchlorum																													R													
Closteriopsis longissima												R																														
Closterium acicularis																											R	R														
C. sp.		R				R										R																										
Coelastrum cambricum																																										
Cosmarium sp.	R				R											R				R	R																			R		R
Cylindrocystis sp.				R														R														U										
Desmidium baileyii					R													R			R																					U
Dictyosphaerium sp.																		R																								
Docidium sp.					R																																					
Elkatothrix gelatinosa																					R																					
Euastrum affine																R																										
E. inerme sp.					R													R			R											C						R				
Gloecystis sp.																								R									R									
Hyalotheca sp.																															R											
Kirchneriella sp.									R																							D										
Micrasterias americana																	R																									
Microspora sp.									R																																	
Mougeotia sp.	U	R		R	R	R		R									R	R				R	R														U	R				R
Netrium sp.																																					R					
Oedogonium sp.																																U		R					R	R		
Oocystis sp.	C	A	C	U	C	U	R	A	R											U	C	R	C	U			R	R				U	C	R	C	U	U	U	U	A	U	U
Planktosphaeria gelatinosa	R	D																														R			R					R		
Phymatodocis sp.																					R																					
Pleuortaenia sp.																								R																		
Scenedesmus sp.				R																																			R	R	R	
Sphaerocystis sp.								A	C											R	R	R	R	U			A	A	U		R		R			R			R	C	C	A
Spondylosium sp.																	R																									
Staurastrum sp.		R	U	R	R	R			R						R		R							R			R															
Tetrallantas lagerheimii																																U									R	U
Tetmenorus laevis																																		R								
Tetraedron hastatum			R																																							
Xanthidium sp.				R															R																							
Unidentified		U					C	C	C						C		A	C		R	D	U	A	D			A	C	A		C	D	D	D	A	A		D	D	D		

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[a] R = rare, 1-5 cells/ml.
U = uncommon, 6-19 cells/ml.
C = common, 20-50 cells/ml.
A = abundant, 51-499 cells/ml.
D = dominant, more than 500 cells/ml.

Table G4. Abundance of green algae (Chlorophyceae) in the Control Pond.

Taxa	Abundance[a]																																									
	6-26-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-73	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	01-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
Green Algae (Chlorophyceae)																																										
Ankistrodesmus falcatus	C	R																				U																				C
A. falcatus var. *turmidus*	R	U																																					R			
Arthrodesmus incus			R			R								R																												
A. octocorni			U	R																																						
Asterococcus limneticus																																				R					R	U
Characium debaryanum														R																												
Chlamydomonas sp.			R		R																																					
Closteriopsis longissima													R																													
Closterium acicularis																												R														
C. sp.			R	R					R								R			R																			R			
Cosmarium sp.		A	C	D	C	A			R																							R							R		R	
Crucigenia apiculata														R	R																											
Cylindrocystis sp.	R					R	R		C					R						R																		R	R			
Desmidium baileyii																R				R												R							R	R		
Dictyosphaerium sp.																		R	NO SAMPLE						NO SAMPLE																	
Docidium sp.																																										
Elkatothrix gelatinosa																							R																			
Euastrum affine																				R												C	C			C	RU					D
E. inerme			R																																							
E. insigne var. *lobulatum*																																							U			
Gloeocystis sp.																				R			R																			
Gonium sociale								R																																		
Gymnozyga sp.									R						R								R																			
Kirchneriella sp.							R	A																																		
Microspora sp.																																									R	
Mougeotia sp.			R														R	R		R														R	A	A	AA			R	R	U
Netrium sp.																																						R				
Nephrocytium limneticum																																	U									
Oedogonium sp.																																A	C	A	C	U		U	A	C		A
Oocystis sp.	A	R			R	U	R	C	U									R		R				D								R		R			R		U		R	A
Pediastrum tetras														R																												
Perioniella sp.							U		R																																	
Planktosphaeria gelatinosa	A	D																																								
Quadrigula dosteriodes		U																																					R			
Scenedesmus sp.	R	R	R	C	U																																		R			
Sphaerocystis sp.								R									R	R				R	R	A															R			
Spondylosium sp.															R	R																										
Staurastrum sp.	R	R	R	U	R															R												R			R		RR		R	R	R	R
Tetmenorus laevis																																							R			
Westella botryoides																				R																						
Unidentified		D					C	A	C						C	A	A	C		A		A	C	D			A	A	C	C	A	A		A	R	R	C		C	R		D

[a] R = rare, 1-5 cells/ml.
U = uncommon, 6-19 cells/ml.
C = common, 20-50 cells/ml.
A = abundant, 51-499 cells/ml.
D = dominant, more than 500 cells/ml.

Table G5. Abundance of Chrysophyceae in the three test pond.

Taxa	Abundance[a]																																									
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	0-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-73	11-16-73	12-04-73	12-19-73	12-29-73	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE TEST POND																																										
CHRYSOPHYCEAE																																										
Botryococcus braunii					R		R	R	R																																	
Chrysococcus rufescens																								R						R												
Dinobryon sertularia					R	R	C	R				R			R			R		R	R	R	U	C						C	R			R		C	A	A		D	A	
Mallomonas akrokomas																																		A								
M. caudata													U	R	R		R	R		R																C		R				
Synura uvella	U	R		R	R	U	U	R	R	R	C	R			U	R				R							U			R										R		
Urogiena americana										A	A	D																														
DRAINED ENGINE TEST POND																																										
CHRYSOPHYCEAE																																										
Botyococcus braunii			R																NO SAMPLE						NO SAMPLE																	
Dinobryon sertularia	R				R			R	R	R		R	R	R						R	U		U	U								R	R	C	C		A	R	U	U		
M. caudata										R	U	R					R	R																		R			R			
Synura uvella	R	R			U	R		R	U				R	R			R											U	U	R												
CONTROL POND																																										
CHRYSOPHYCEAE																																										
Botryococcus braunii								R	U																																	
Chromulina sp.		C																																								
Dinobryon sertularia	R			R	U	R	R	R				R	R	R	R			R		R	U	R	U	R								C	U	U				C	R			A
Mallomonas akrokomas																																		U	A							
M. caudata					U	R											U																	C	R							A
Prymnesium sp.		A		R																																						
Synura uvella	R							R																			A	U	R													

[a]
R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml
C = common, 20-50 cells/ml
A = abundant, 51-499 cells/ml
D = dominant, more than 500 cells/ml

Table G6. Abundance of Dinophyceae in Control Pond, Drained Engine Pond, and Drainless Engine Pond.

Pond/Taxa	Abundance[a]																																									
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-73	11-16-73	12-04-73	12-19-73	12-29-73	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE TEST POND																																										
DINOPHYCEAE																																										
Ceratium cornutum										R	R	R		R	R	R	R	R													R											
Gymnodinium sp.	R									R																				R												U
Peridinium cinctum	R	R	R	R	R	R	R			R	R	R				R		R		R	R		R								R		R	U					R		C	
P. umbonatum			U	R		A	R	U	R	U		C	U		R	R	R	R		R	R	R	R				R															
P. wisconsinense							R	R																			R			R												
DRAINED ENGINE TEST POND																																R										
DINOPHYCEAE																																										
Ceratium cornutum										R							R	R																								
Glenodinium gymnodinium																			NO SAMPLE						NO SAMPLE								R									
Gymodinium sp.		R													R	R																			R							U
Peridinium cinctum	U	U	C	R	R	U		C	R						R	R	R	R			R		R								R			R		U	A		C	C		A
P. umbonatum	R				U			U	U		R	R	R			R					R													R								
P. wisconsinense								R		R																																
CONTROL POND																																										
DINOPHYCEAE																																										
Ceratium cornutum													R	R	R	R	R	R																	R						U	R
Glenodinium gymnodinium								R																																		
Gynodinium sp.	R														R			R												R												
Peridinium cinctum	R					R	C	R	U						R	R		R		R	R	R	R					R						R	R							R
P. umbonatum				A		U	A	R	A			R	U	R	R	R		R			R		U				R															
P. wisconsinense							R	U	A		R		R	R																												

[a] R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml
C = common, 20-50 cells/ml
A = abundant, 51-499 cells/ml
D = dominant, more than 500 cells/ml

Table G7. Abundance of Bacillariophyceae in Drainless Engine Pond, Drained Engine Pond, Control Pond.

Pond/Taxa	Abundance[a]																																									
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-73	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE POND																																										
BACILLARIOPHYCEAE																																										
Cyclotella sp.		A																									R	R														
Denticula sp.																											R		R													
Eunotia sp.																																		R							R	R
Frustulia sp.																																				U		C			C	
Neidium sp.																																				R						
Melosira granulata			R						R																																	
Melosira sp.																																		R								C
Navicula sp.			R			R					R	R			R		R		NO SAMPLE					R	NO SAMPLE		R		R	R			U					R		R	C	
Nitzschia closterium																																				R		R			R	
N. longa					R																																					
Pinnularia sp.																																									R	
Synedra sp.											R	R				R	R	R																								U
DRAINED ENGINE TEST POND																																										
BACILLARIOPHYCEAE																																										
Cyclotella sp.		C																																								
Eunotia sp.																																						R	R			R
Melosira italica							R																																			
Navicula sp.												R						R			R			R			U								R	R						
Nitzschia closterium																																R						RU	R			
N. longa					R	R																																				
CONTROL POND																																										
BACILLARIOPHYCEAE																																										
Cyclotella sp.				R																														R								
Eunotia sp.																																R										
Frustulia sp.																																				R		A		R		
Melosira granulata							R	R																																		
Navicula sp.								C														R										R			R	R					U	
Nitzschia closterium			R				R																																			
N. longa																																			R							
Synedra ulna		R																																								
Synedra sp.																	R																									

[a] R = rare, 1-5 cells/ml.
U = uncommon, 6-19 cells/ml.
C = common, 20-50 cells/ml.
A = abundant, 51-499 cells/ml.
D = dominant, more than 5000cells/ml.

Table G8. Abundance of Crypotophyceae in Control Pond, Drained Engine Pond, Drainless Engine Pond.

Pond/Taxa	Abundance^a																	
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-73	3-22-72	4-04-72	4-20-72
DRAINLESS ENGINE TEST POND																		
CRYPTOPHYCEAE																		
Cryptomonas erosa			U	U	R	U		R					R			R	R	R
C. ovata								R	R	R			R					
Rhodomonas sp.								U	U									
DRAINED ENGINE TEST POND																		
CRYPTOPHYCEAE																		
Cryptomonas erosa		C	R		U	R				U	U	R		R	R		R	R
C. ovata					R			R	R									
Rhodomonas sp.								U	A									
CONTROL POND																		
CRYPTOPHYCEAE																		
Cryptomonas erosa		A	R		R			R	C			R	R	R	R	U		R
C. ovata								U										
Rhodomonas sp.							A		C									

Pond/Taxa	Abundance^a																							
	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE TEST POND																								
CRYPTOPHYCEAE																								
Cryptomonas erosa		U				U				R														
C. ovata																								
Rhodomonas sp.						U																		
DRAINED ENGINE TEST POND	NO SAMPLE						NO SAMPLE																	
CRYPTOPHYCEAE																								
Cryptomonas erosa		R				U																		
C. ovata																								
Rhodomonas sp.						R													R					R
CONTROL POND																								
CRYPTOPHYCEAE																								
Cryptomonas erosa		A				R			R	C		C												R
C. ovata																								
Rhodomonas sp.						U						R												

^{a}R = rare, 1-5 cells/ml.
U = uncommon, 6-19 cells/ml.
C = common, 20-50 cells/ml.
A = abundant, 51-499 cells/ml.
D = dominant, more than 500 cells/ml.

Table G9. Abundance of the Chloromonadida in Control Pond, Drained Engine Pond, Drainless Engine Pond.

Pond/Taxa	Abundance[a]																				
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-73	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72
DRAINLESS ENGINE TEST POND																					
CHLOROMONADIDA																					
Gonyostomum semen																					
DRAINED ENGINE TEST POND																			NO SAMPLE		
CHLOROMONADIDA																					
Gonyostomum semen																					
CONTROL POND																					
(None Present)																					

Pond/Taxa	Abundance[a]																				
	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE TEST POND																					
CHLOROMONADIDA																					
Gonyostomum semen										C											
DRAINED ENGINE TEST POND				NO SAMPLE																	
CHLOROMONADIDA																					
Gonyostomum semen										A											
CONTROL POND																					
(None Present)																					

[a] R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml
C = common, 20-50 cells/ml
A = abundant, 51-499 cells/ml
D = dominant, more than 500 cells/ml.

Table G10. Abundance of Euglenida in Control Pond, Drained Engine Pond, and Drainless Engine Pond.

Pond/Taxa	Abundance[a]																																										
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-73	11-16-73	12-04-73	12-19-73	12-29-73	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73	
DRAINLESS ENGINE TEST POND																																											
EUGLENIDA																																											
Euglena sp.												R															R																
Menoidium incurvum																											R																
Peranema trichophorum					R																																						
DRAINED ENGINE TEST POND																			NO SAMPLE						NO SAMPLE																		
EUGLENIDA																																											
Phacus phyrum								R																																			
Petalomonas praegnans				R	R																																						
Trachelomonas volvocina																													R														
CONTROL POND																																											
EUGLENIDA																																											
Euglena sp.				R	R					R	R	R															R																
Menoidium incurvum																																											
Phacus phyrum																																											U
Trachelomonas volvocina												R								R																							R

[a] R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml
C = common, 20-50 cells/ml
A = abundant, 51-499 cells/ml
D = dominant, more than 500 cells/ml

Table G11. Abundance of Ciliophora in Drainless Engine Pond, Drained Engine Pond, and Control Pond

Pond/Taxa	Abundance[a]																																									
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-73	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-72	11-16-72	12-04-72	12-19-72	12-29-72	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE Pond																																										
CILIOPHORA																																										
Aspidisca costata																												R														
Cyclidium glaucoma			R			R	U		U		U	U	R	R				R										R														
Halteria grandinella				R	R	R										R		R										R										R				
Nannophyya sp.																																										
Paramecium chlorelligera																	R																									
Plagiophrys sp.																R																										
Proroden sp.																R																										
Strobilidium sp.	R																																									
Strombidium sp.	U			R				R	R	R			R		R	R	R	R										R		R	R		U									
Unidentified				R		R				R	R	R																R						R		R				U		
DRAINED ENGINE Pond																																										
CILIOPHORA																																										
Aspidisca costata																			NO SAMPLE						NO SAMPLE																	
Cyclidium glaucoma			U	R		R					R		R		R		R													R												
Halteria grandinella	R	R	R	R	C	R												R									R	R			R											
Mesodinium acorus		R																															U									
Nannophyya sp.										R	R	R																														
Strombidium sp.	R		R	R		R		R	U	R	R	R	R	R	R	R		R									R	R		R	R		R	C		U						
Unidentified						R																								R	U		R	R		R	R	C	U			C
CONTROL POND																																										
CILIOPHORA																																										
Aspidisca costata																																										
Cinotochilum margaritaceum																										R																
Cyclidium glaucoma	R	R				R					R	R			R	R		R																								
Halteria grandinella		R		R										R		R		R								R																
Lembus fusiformis	U																																			R						
Mesodinium acorus	R																																									
Nannophyya sp.										R															U	R																
Oxytricha chlorigellera	R																																									
Strombidium sp.				R	R	R	C		R	R		R													R	R	R	R				U			U							
Unidentified									R	R		RR														R	R				R							A	U			

[a] R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml
C = common, 20-50 cells/ml
A = abundant, 51-499 cells/ml
D = dominant, more than 500 cells/ml

Table G12. Abundance of Zooflagellida in Control Pond, Drained Engine Pond, Drainless Engine Pond.

Pond/Taxa	Abundance[a]																			
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72
DRAINLESS ENGINE Pond																				
ZOOFLAGELLIDA																				
Biocera sp.			R		R														NO SAMPLE	
Bodo sp.			R																	
Monas sp.			R																	
Monosiga ovata																				
Unidentified			C		C	A														
DRAINED ENGINE Pond																				
ZOOFLAGELLIDA																				
Biocera sp.																				
Bodo sp.																				
Monas sp.		R																		
Monosiga ovata																				
Unidentified		U																		
CONTROL POND																				
ZOOFLAGELLIDA																				
Biocera sp.		R																		
Bodo sp.																				
Monas sp.																				
Monosiga ovata		U																		
Unidentified		A																		

Pond/Taxa	Abundance[a]																					
	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-73	11-16-73	12-04-73	12-19-73	12-29-73	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE Pond																						
ZOOFLAGELLIDA																						
Biocera sp.		U			NO SAMPLE																	
Bodo sp.																						
Monas sp.																						
Monosiga ovata																						
Unidentified	U	R	C	D												R	C	R	R			R
DRAINED ENGINE Pond																						
ZOOFLAGELLIDA																						
Biocera sp.																						
Bodo sp.																						
Monas sp.																						
Monosiga ovata																						
Unidentified	R		U	A								C										C
CONTROL POND																						
ZOOFLAGELLIDA																						
Biocera sp.																						
Bodo sp.																						
Monas sp.																						
Monosiga ovata																						
Unidentified																						

[a] R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml
C = common, 20-50 cells/ml
A = abundant, 51-499 cells/ml
D = dominant, more than 500 cells/ml

Table G13. Abundance of Rhizopoda in Control Pond, Drained Engine Pond, Drainless Engine Pond.

Pond/Taxa	Abundance^a																																									
	6-28-71	7-05-71	7-28-71	8-03-71	8-17-71	8-27-71	9-15-71	9-21-71	10-18-71	11-24-71	12-02-71	12-15-71	1-31-72	2-10-72	3-02-72	3-22-72	4-04-72	4-20-72	May	6-22-72	7-28-72	8-07-72	8-17-72	8-24-72	September	October	11-10-73	11-16-73	12-04-73	12-19-73	12-29-73	1-04-73	1-15-73	1-22-73	2-02-73	2-19-73	2-26-73	3-02-73	3-09-73	3-16-73	3-26-73	4-02-73
DRAINLESS ENGINE Pond																																										
RHIZOPODEA																																										
Amoeba radiosa					R																																					
DRAINED ENGINE Pond																																										
RHIZOPODEA																																										
Amoeba radiosa				R	R								R																													
Clathrulina elegans														R																												
Difflugia lebes		R		R	R	R																																				
CONTROL POND																																										
RHIZOPODEA																																										
Acanthocystis aculea							U												NO SAMPLE							NO SAMPLE																
Psuedodifflugia gracilis																						R																				

[a] R = rare, 1-5 cells/ml
U = uncommon, 6-19 cells/ml
C = common, 20-50 cells/ml
A = abundant, 51-499 cells/ml
D = domiant, more than 500 cells/ml